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The Cracking of Reinforced and Plain Concrete Arches.

The cracking of any masonry structure, exhibiting the actual parting or separation of material which ought to exhibit continuity of texture, is to some extent disturbing. It seems to carry to the mind an impression of weakness where every feature of the structure ought to convey an impression of strength. This is particularly the case where cracks are so obvious or assertive in character, so to speak, as in the plain surfaces of concrete or reinforced concrete structures, although as a matter of fact cracks in stone masonry, whether in arches or other structures, are by no means uncommon. There are many arches, retaining walls and other similar structures built of stone masonry where cracks have appeared soon after completion, or even before, and will remain indefinitely without prejudice to stability. In general, however, in such cases the designed unevenness of surface or the natural joints of stone masonry make defects far less apparent than in the smooth, plain surface of concrete. The cracks being less apparent and fitting more suitably to the general character of stone masonry, they attract there much less attention and seem to have much less significance, whereas there is no material difference in the meaning of such defective features.

These observations evidently apply to those cracks, caused by the expansion and contraction of the masonry or any slight irregular settlement, which, while parting the material in some places, produce damage chiefly serious in appearance only. Cracks which result from structural weakness, due to bad design or serious settlements or from any other cause of sufficient gravity to prejudice or throw under reasonable suspicion the capacity of the structure, are of a different class; they are dangerous and demand the application of remedial measures promptly and sometimes to a radical extent. It is necessary, however, both in concrete and in stone masonry, to differentiate carefully between these two classes of defective features, one without any serious significance and chiefly objectionable in appearance, while the other threatens the stability or safety of the structure. The character of masonry, whether of concrete in mass or in blocks, or of stone, is such that it has practically no capacity to resist slight distortion without cracks, whereas steel will sustain distortion to a degree ruinous to the structure in which it is found before it actually parts. These elementary but fundamental considerations indicate the significance of the cracks in any class of masonry whatever.

In the last issue of The Engineering Record there is given a brief statement of the cracking of some reinforced concrete arches at South Pasadena, Cal., the longest span apparently being under 80 ft. in length. As will be seen from the illustration the reinforcement is almost entirely along the soffit of the arch and at the pier, the stirrups interlacing at the latter location. Serious cracks have opened in the spandrel masses at a number of points, none so far as known extending into the soffit. Although these cracks are most unsightly and apparently serious in the early morning, they diminish in width as the temperature rises until in the warmest part of the day they are nearly closed. Without more information than is at hand regarding the loading and design of these arches it is impossible to determine just how serious the cracks are. It is obvious that the closure under the action of the sun is produced by simple expansion of the concrete, and it is not unlikely that if the highest temperature of the afternoon were maintained the cracks would arrest much less attention than under the actual conditions. Something is clearly wrong when a concrete or other masonry arch exhibits such features of construction, but a conclusion as to dangerous weakness should not be too hastily reached. One serious feature of this particular case arises from the opening and closing motion due to variations in temperature, as this may lead to an extension of the actual parting of the material and eventually produce serious results.

If the design of reinforced concrete arches like those under consideration may be made without regard to the elastic properties introduced by the reinforcement, so as to make the stability of the structure identical with that of a series of masonry blocks, manifestly there might be considerable cracking without any material injury, just as is frequently seen in stone masonry arches which have stood for long periods of time without the slightest prejudice to their safety. Such cracks as those indicated in the Pasadena arch, however, have no sufficient reason for their being; under careful design and efficient management in construction such results are scarcely possible.

There are cases of reinforced concrete design where the dimensions are fixed upon the assumption that the arches are block-work structures, even though steel reinforcement is introduced, and in connection with which temperature or similar cracks would have no material significance. Indeed, from one point of view cracks in such cases may be considered simply the imaginary joints between the blocks assumed in the computations. Whether they are of zero dimension or open sufficiently to be evident to the unaided eye is not a matter of much consequence so far as the stability of the structure is concerned. They are more or less offensive to the eye, and as such they are to be avoided as much as possible. At the same time, under conditions like those attending a continuous series of arches not jointed either at crown or springing it is not more necessary to provide for expansion and contraction than if those arches were built of stone blocks. Some cracks are bound to appear when such structures are built of either plain or reinforced concrete and their existence need give no uneasiness as to unfailing stability, but as a matter of appearance it is advisable that they should exist where they are not prominent or offensive.

Some Aspects of Electrical Heating.

The approach of the season when heating is a matter of much interest brings into consideration the subject of warming by electric means. Electric car heating is now so common as to attract little attention, but the use of electric heaters for warming rooms and other purposes has been very little discussed. Central stations here and there have been devoting some attention to the subject for a few years past, especially in connection with flat-irons, but it has not been pursued with much vigor save in a few instances. There has been much hesitation in favoring a use for energy in which full lighting rates are evidently out of place, even when rates profitable in themselves can be obtained. There are at present available all sorts of heating appliances at reasonable prices and of good quality which would give the central stations good revenue if their use were encouraged, and the load is one which in itself has usually proved to be desirable in that it tends to level up the hollows in the load curve. Moreover, it is a use that when once made economically possible will persist, while some other popular uses will not. For example, the very extensive use of electric signs now evident is one that may feel severely the first incursion of hard times, as representing a fashion rather than a daily necessity of commerce. Once get electric appliances into the household, shop or factory, however, and they will stay so long as they give good and reasonably economical service. On the other hand, appliances the practical value of which is not immediately evident, are easily displaced.

The policy of the gas companies has been very far-sighted in this respect. Instead of making rates to penalize the small consumer, they have favored him, perhaps even unduly. They have made it possible by persistent and liberal exploitation, for the small consumer to be introduced on an economic basis to all manner of gas-heating appliances, and they are getting ready to raid the motor business with small gas engines in a way that may before long be felt. The moral effect of this policy is at once felt through the community. A householder who finds that a gas range is cheaper than a coal range, and that a gas log is not to be despised as an occasional auxiliary heater, will generally not think it worth his while to run an additional bill for electric lights; and he is an easily made friend of the gas engine. That is the policy the central station people must adopt—to develop every field, old and new, that promises ultimate profits, and to occupy it so fully that the other fellow cannot get a foothold. The electric heating appliance business at the prices of energy ordinarily met cannot at present be a very large item, but in certain plants it can be made thoroughly profitable as a source of additional load. Once show a man that electric cooking apparatus and the like is wonderfully handy and reasonably cheap, and he will keep it in use and add to the station's revenue year after year. In summer and in the warmer parts of our country, this line of work can be followed up with good results, especially when the station uses hydraulic power. Some of the Southern California plants have built up quite a large business in this way, selling energy at 3 to 4 cents per kilowatt-hour and competing very successfully with gas at, say, $1.50 per thousand cubic feet.

Attempts at ordinary air heating by electricity have not been satisfactory at a similar price, nor is it to be expected. On the other hand, gas for this purpose fails in similar fashion, save as an occasional auxiliary. Gas heat as ordinarily used is extremely bad from the hygienic standpoint. It vitiates the air very seriously indeed, and the moisture produced by the combustion makes itself a nuisance unless there is thorough ventilation. Of course, there are places where coal is high enough in price to give electric heating a chance. It has even now been found that electric radiators can be made useful in bathrooms, bedrooms and the like, at a cost that is not prohibitive. With energy down to 2 or 3 cents per kilowatt-hour, and especially when its use for this sort of work can be kept off the peak of the load, there is chance for a growing business. Of course, it is clear that there are many plants which could not profitably meet such a price. On the other hand, there are many which can and do make such quotations even for load carried over the peak. The miscellaneous thermal uses of electricity can be carried at better prices, air heating representing the least general and most unfavorable case. There are plenty of hydraulic plants where a thousand kilowatt-hours per day of off-the-peak load would not be looked at with contempt even at 3 cents per unit. It should be noted, too, that this kind of load, being mainly off the peak, does not bear heavily on the capacity of transformers or distribution system. At the price mentioned, electric kitchen equipment is not outclassed in economy by either coal or gas. Experience has shown that 3-cent energy is about on a par with dollar gas in cooking apparatus, and it is reasonably certain that dollar gas is cheaper than anthracite at the cost now common away from the anthracite districts. Even with energy at 4 to 5 cents per unit, the electric cooking and miscellaneous heating is on a par with the use of coal at $6 to $7.50 per ton. Granting for the present that heating on a large scale by electricity is too costly, there still remains a chance for putting in the auxiliary and miscellaneous heating appliances on a sound economic basis. The gas companies make no pretense of competing with coal for general house heating, but they derive a large revenue from just the class of work here referred to, a revenue which is probably available if the central station will really get after it in earnest.

The Contract System for the Panama Canal.

The Isthmian Canal Commission has announced that the construction of the Panama Canal is to be done by contract on a percentage basis, thus putting this great work on a par with many large undertakings for private corporations. This announcement comes as something of a surprise, for while it was known that the Commission was looking into the percentage system quite thoroughly, it was not believed possible for it to be adopted, owing to various legal difficulties that have prevented the adoption of the plan on other Government undertakings for which it was specially adapted. Whether the plan will stand the test of legal attack in the courts remains to be seen, and the result will depend in no small measure on the care with which the basic principle underlying this form of contract is brought out in the document. This principle is, in substance, that the contractor is an agent or employe and not a true contractor.

The importance of this distinction is apparent on examining the general plan proposed by the Commission. It will furnish materials of construction to the contractor, and turn over to him all the Government plant now in use, including the railway. The contractor is also to take over all employes on the Isthmus whom the Commission does not require. The Commission is to retain control of all engineering work, including that for the cities in the Canal Zone, the police, sanitary, hospital and commissary departments, mess houses, quarters, the construction and maintenance of buildings, the operation of the Panama Railway, an auditing department to which the contractor's accounts are to be open, and a department of materials and supplies. It is expected that the bids, which will be opened on Dec. 12, will come from associations of contractors, each a specialist in some line. The proposals are to be expressed in terms of a percentage on the cost of construction, which is to be determined by a board consisting of the chief engineer of the Commission and two engineers appointed by it, with two engineers appointed by the contractor. This board will also estimate a reasonable time for the execution of the work and fix a system of premiums and penalties for rewarding fast progress and fining a slow rate of construction.

Without going into a careful examination of each clause in the contract form, which has not been possible in the brief time since the publication of its details, it is evident that the system is simply the familiar one of employing a contractor as a construction superintendent, paid a certain percentage of the actual cost of the work instead of a salary. The Commission very frankly states that, in the present state of the contracting business, it will take it years to get together such an organization for carrying on great construction undertakings as the leading contracting firms already possess. The labor condition is a particularly difficult one for the Government to handle, although it will not be particularly troublesome to contractors in all probability. The financial resources of the Government will be utilized to secure the prompt and economical purchase of supplies of a character satisfactory to the Commission, and the contractor, although required to prove his possesion of free assets of five million dollars, is not required to finance the work in the manner necessary in other methods of contracting. He is given an incentive to make good time and avoid delays, and is represented on the board which determines the actual cost of the work, i. e., the basis of his profits. On the other hand, the Commission is able to free itself of the difficulties of engaging and managing directly a great force of laborers and skilled mechanics. It can let its contract before its plans are prepared and can take from now until doomsday to determine the essential details of the great waterway. This is an important matter because it is generally understood that grave doubts have arisen concerning the practicability of some of the leading features of the plans prepared by the minority of the Board of Consulting Engineers. Under the circumstances, it was the part of wisdom for the Commission to adopt the plan it did for the construction of this great work, as by so doing it will be able to devote its entire attention to executive and engineering problems, and unload the construction work upon the shoulders of private parties better able to carry it out.

Electrical Methods of Measuring Temperatures.

So much attention is now being paid to the determination of high temperatures in industrial processes where a rough guess was formerly considered good enough for practical purposes, that it is well to call attention to the two different methods of measuring temperature electrically, namely, the e.m.f. method and the resistance method. These are totally different and depend upon different properties of metallic substances. The e.m.f. method depends upon thermoelectric action. According to the electronic theory, if a certain metal, say copper, possesses a given average number of free negative corpuscles per cubic centimeter, while at the same temperature iron possesses a larger number of such free corpuscles, then, when these two metals are brought into contact the iron will tend by surplusage to diffuse free corpuscles across the mutual bounding surface at the junction, and the copper will be made negative by the reception of negative electricity, while the iron will correspondingly become positive. Since the rate of diffusion of free corpuscles increases in each metal with the temperature, so, also, will the e.m.f. of the junction. In order to have a resultant thermal e.m.f. in a closed bimetallic circuit, a difference of temperature is, of course, necessary between the two junctions. Conversely, by the measurement of this resultant e.m.f., the difference of temperature becomes known. The resistance method depends upon the fact that metals increase in resistivity with temperature. According to the electronic theory, the mean free path of the corpuscles in metal diminishes as the temperature rises. This has the same effect on the electric conductivity as though the length of path remained unchanged, but the number of free corpuscles diminished. But however we try to form a mental picture of the action, the fact is perfectly definite that at the standard temperature of melting ice, pure metals increase in resistivity about four-tenths of one per cent. per degree Centigrade. Moreover, the rate of increase follows a straight-line law with respect to temperature up to at least 100° C. For high temperatures there appears to be a deviation from the straight-line law, in some metals at least.

An interesting paper on the measurement of temperature by electrical means was read at the Milwaukee Convention of the American Institute of Electrical Engineers by Dr. Edwin F. Northrup. The paper is addressed almost entirely to the resistance method, and suggests a number of important details in the technique of the manufacture, use and maintenance of resistance thermometers, such as go to make the difference between satisfaction and dissatisfaction in their application. In the first place, a special brand of nearly pure platinum is recommended for its uniformity and relatively high temperature coefficient. Then precautions have to be taken to prevent the platinum from dissolving or absorbing metallic vapors at high temperatures.

Pure nickel wire is also recommended for moderate temperature thermometers. The beautiful principle of the Kelvin double Wheatstone bridge is also recommended for use with low-resistance thermometers. In such cases the resistance coils can be made very compact, and of dimensions comparable with those of a thermo-junction. For direct reading purposes a special form of D'Arsonval differential galvanometer, called a ratiometer, is described, in which the control is magnetic instead of elastic. That is, the coils lie flat in a dissymmetrical magnetic field, such that the differential magnetic actions cause the movable system to seek a definite magnetic displacement. The three leading-in wires are arranged to exert jointly a negligible torque about the axis of pivot rotation. Some of the results reported with the various types of instruments described constitute jointly a valuable research on temperature measurement and its automatic recording, and will prove directly useful to those responsible for the operation of plants in which it is desirable to maintain temperatures of a uniformly high degree. The enormous waste of fuel caused by overheating, apart from defective characteristics of the products of high-temperature operations not under close thermometric control, make this subject one of much technical importance.

The Hudson River Tunnel of the Pennsylvania R. R.

The meeting on Monday night of the two headings of the south tube of the Pennsylvania R. R. tunnel under the Hudson River marked the completion of the first stage of an engineering and construction feat of the first magnitude. It is particularly gratifying because it completely disproves the assertions diligently spread by financial influence adverse to the Pennsylvania R. R. that its Hudson River tunneling operations were a failure and the tunnels would be abandoned as impracticable before the end of the year. Such stories have had a wide circulation and without doubt were believed by many people; in fact this journal has been asked from time to time to verify reports that the alignment of the tunnel could not be maintained on account of the buoyancy of the tubes, which seems to have been a favorite argument in Wall Street among the bears on the stock. The fact that the two headings of the north tunnel met within a sixteenth of an inch and those of the south met accurately shows how baseless have been the rumors of insurmountable troubles in the prosecution of the work.

The rapid completion of the two tubes, each one and one-eighth miles long, has not been a matter of good luck. The history of other tunneling operations under the same stream teaches that the record just made is primarily due to the engineering ability and ripe experience in similar work of the chief engineer and the intelligently applied energy and complete organization of the contracting company. When it it considered that the tunnel has been driven down to a depth of about 90 ft. below the mean high-water level, probably 25 ft. below the river bed, the character of the undertaking can be understood. Moreover the diameter of the shields added to the difficulty of the work, for the larger a shield the greater the troubles to be expected in keeping out rushes of water and preventing blow-outs. The outside diameter of the 1½-in. cast-iron lining of each of these tubes is 23 ft., which will indicate to those acquainted with subaqueous tunneling some of the serious problems which must have been overcome in handling the shields under heavy air pressures. Accordingly, the story of the operations, if it is ever made public, will be one well worth studying.

Although the two tubes of the tunnel are now joined, it will probably be a year or more before the work will be completed. The massive cylindrical cast-iron piles, 27 in. in diameter and 15 ft. apart, must be screwed down to afford a support for the tracks. This work will probably not be specially difficult, although novel, for experiment has shown that the piles can be screwed down by hydraulic machinery, and there is no apparent reason why electrical apparatus cannot be employed for the purpose. Special plugs of large size have been inserted in the bottom of the tunnel lining at places where the piles will be sunk, and it will not be necessary in consequence to cut out any of the metal in order to start these operations. The lining of the tubes with concrete must also be carried out, and recent experience has shown that this is a class of work which must be given much careful attention. The arch concrete is 2 ft. thick down to the banquette on each side, in which the various conduits are located, and an examination of the cross-section of the tubes, published in this journal on Oct. 10, 1903, will show that this concrete construction, the laying of the track in each tube and the running of the wires and cables will require considerable time under the working conditions which obtain in the narrow confines of a subaqueous tunnel.

The Place for Pumps in Power Plants.

The location of the pumps in a power plant depends so largely upon the available space that in many cases the designer has little choice in the matter. Fortunately there is a wider latitude usually to be found in the location of equipment in a central station than in an installation for office building or hotel service, although in some of the higher-class isolated plants, a separate room is now provided for pumps, and there is no doubt that in many generating stations such a course would be advantageous.

In some cases the pumping equipment is installed in the engine room, and the principal advantage of so doing is the increased amount of attention the pumps receive from the engineering staff of the station. In general the boiler room is not an ideal place for moving machinery, and although steam-driven feed and circulating pumps are rugged pieces of apparatus, there is no question that constant exposure to coal dust and dirt increases the rate of depreciation. Pumps and piping need care as well as anything else, and it is too much to expect the same attention in the boiler department as in the engine room.

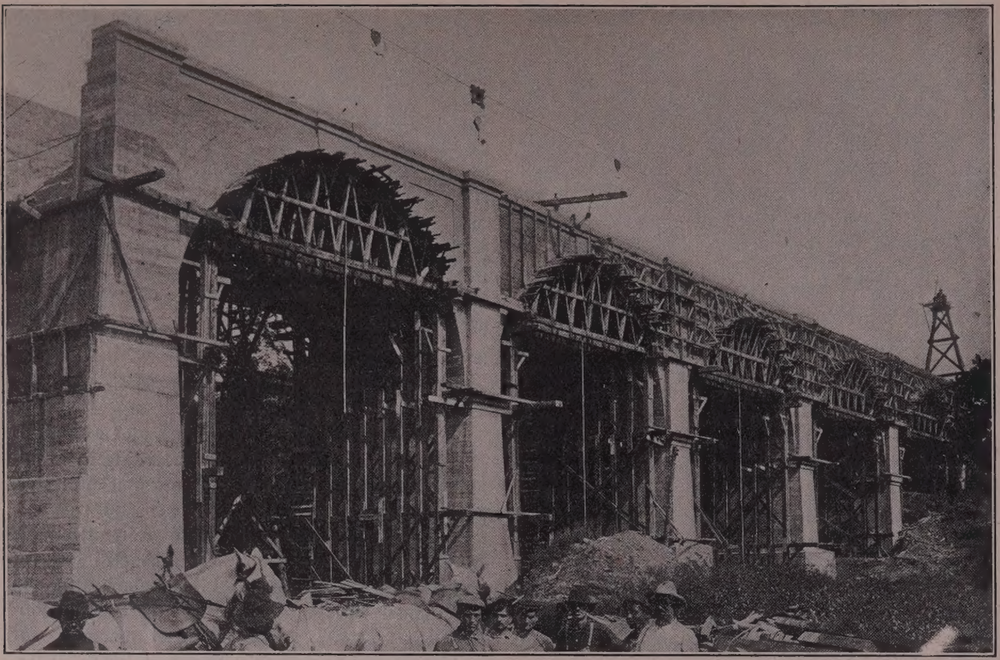
The location of pumps in the engine room is open to the serious objection that such a course tends to crowd the equipment too closely together in plants where there is quite a number of pumps to be installed. Aside from boiler feed pumps, many plants are equipped with air and circulating pumps for condenser service, step bearing turbine pumps, oil pumps, drainage, artesian well and fire pumps. The piping complications which these entail are an obstacle to free movement in the engine room, and to clear supervision by the operating force. The most modern stations are conspicuous for the way in which similar equipment is co-ordinated in groups of operating units; ample clearance is allowed between units, and the grouping plan permits the widest flexibility in case of trouble. Thus, if all the boiler feed pumps are installed in a parallel row in a separate pump room the piping can readily be arranged to enable any pump to take up the load with minimum loss of time in case of trouble. If the pumps are scattered promiscuously around in odd corners, the pipe layout cannot be as simple, and hence as low in first cost, or the control so immediate and concentrated. Air and circulating pumps are almost always installed in the basement close by the condensers which they serve, but there is often the same opportunity for co-ordinating these in a group, with the feed and oil pumps, step bearing pumps, etc., that there is when the pumps are located in a separate compartment on the floor above. The pump installation ought to be well under the hands and eyes of the operating shift, in any case, and the plan of segregating this equipment in a group apart from the boiler and engine room apparatus is well worth bearing in mind in designing new plants. There is no reason why traditional practice in the location of pumps in the boiler room should not be departed from in cases where it seems advisable.

Notes and Comments.

Conditions in San Francisco at the end of August are very encouraging, according to a bulletin of the California Promotion Committee. The population was about 370,000 and was expected to increase rapidly, many new dwellings were about completed. There was still a great demand for skilled and unskilled labor, although 30,000 men were estimated as employed on construction. During August 1,176 permits for buildings estimated to cost $6,333,000 were issued, 170 contracts for buildings estimated to cost $1,429,000 were recorded, and 711 buildings worth $50,000,000 were under construction. In cleaning up the city about 125 car loads of debris were removed daily.

The Effect of Timber Preservative Methods on the strength of cross-tie woods has been investigated by the United States Forest Service at its testing stations at the St. Louis Exposition and Purdue University. A preliminary report on the results of the investigation has recently been published by Prof. W. K. Hatt, in which the following general conclusions are given: (1) A high degree of steaming is injurious to wood. The degree of steaming at which pronounced harm results will depend upon the quality of the wood and its degree of seasoning, and upon the pressure (temperature) of steam and the duration of its application. For loblolly pine the limit of safety is certainly 30 lb. for 4 hours, or 20 lb. for 6 hours. (2) The presence of zinc chlorid will not weaken wood under static loading, although the indications are that the wood becomes brittle under impact. (3) The presence of creosote will not weaken wood of itself. Since apparently it is present only in the openings of the cells, and does not get into the cell walls, its action can only be to retard the seasoning of the wood.

Descriptions of Building Conditions issued by architects and engineers as guides to contractors in making up bids are usually accompanied by a disclaimer of responsibility for their accuracy. The necessity for this, as a matter of justice to both parties where the reasonable correctness of the data is not assured, is shown by the following sentence from the opinion of the New York Court of Appeals in Langley v. Rouss, 77 N. E. Rep. 1168: "Where the amount of work to be performed and materials to be furnished under and by a contract depend upon conditions that cannot be ascertained by inspection, and bidders are not required and given an opportunity to make such investigations as are necessary to satisfy themselves as to the amount of work to be done and materials to be furnished, and the contract, plans and specifications include representations as to existing conditions which are inserted for the purpose of enabling contractors to determine what bid to make for the proposed work and materials, a recovery may be had as for a breach of contract for the damages caused if it shall turn out that the representations were erroneous."



Forms, Arch Centers, Falsework and Cableway for Pennypack Bridges.

DOUBLE-TRACK AND FOUR-TRACK CONCRETE BRIDGES ON THE PHILADELPHIA & READING R. R. LINES.

The double track of the New York Short Line R. R., belonging to the Philadelphia & Reading system, crosses the Pennypack Creek about 12 miles from Philadelphia, on a concrete bridge 348 ft. long over all, about 80 ft. at the extreme height above the bottom of the river bed, and nearly 33 ft. wide over all. It is a monolithic structure without reinforcement, and comprises five full center arches of 60-ft. span supported by two end abutments and four intermediate piers. The surface of the ground slopes from a height of about 6 ft. below the springing line at one abutment to 38 ft. at the other abutment. Both abutments serve as retaining walls for the embankments for which the tracks approach the bridge and are, therefore, made with an increased thickness which in the tall abutment reaches a maximum of nearly 18 ft. at the surface of the ground.

The embankment slopes are backfilled on both sides of the abutments, thus carrying the slope under the end spans of the bridge. At one end this slope extends beyond the foot of the first pier, and the latter is therefore provided with an increased batter on the opposite side to give it additional stability against the horizontal thrust and thus presents an unsymmetrical appearance in the drawing, although this feature is not noticeable in the structure where it is nearly obscured by the embankment. The foundations were built in open pits and were made with concrete footings. The piers have uniform symmetrical loads and their shafts are made 8 ft. wide and 34 ft. long under the coping with a batter of 1:24 on all sides. The two channel piers are provided with pointed cut waters at both ends, which are carried up above high water.

The arches have a radial thickness of 3 ft. at the crown increasing over the haunches to a maximum of 11 ft. on the center lines of the piers where the upper surfaces intersect. The faces of the arch terminate in the planes of spandrel walls, which, like the piers, are carried up to the level of the base of rail and are finished with two slightly projecting coping courses with moulded corners as shown in the accompanying detail drawing. The faces of the walls have triangular panels in the spandrels and are moulded to emphasize the lines of the arch ring and of a keystone-like projection at the crown. The upper surface of the arch pitches 0.5 ft. to the axis of the bridge where the water collects and is drained by 4-in. pipes built into the masonry at the center of each pier. Like all exposed horizontal surfaces it has a 1-in. coat of 1:2 Portland cement mortar with a hard trowel finish. All other exposed surfaces have a smooth plain finish pointed and rubbed where necessary. All edges and angles of the pier, abutments, and coping are slightly rounded.

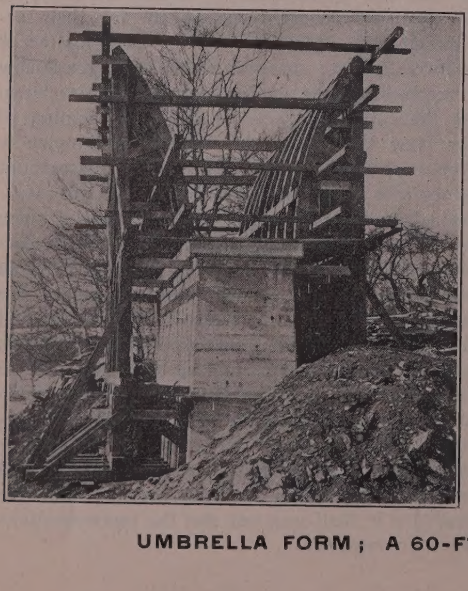
Vertical transverse expansion joints are provided in the spandrel walls, two over each pier, extending from the haunches to and through the coping. These were made by first constructing the portion of the spandrel over the pier included between the sides of the pilaster, with rectangular grooves which engaged a corresponding tongue constructed on the adjacent spandrel walls. These tongues and grooves were about 6 in. deep and in width were made one-third the thickness of the wall. The adjacent faces of the wall are separated by two thicknesses of corrugated asbestos board, making about a half inch clearance.

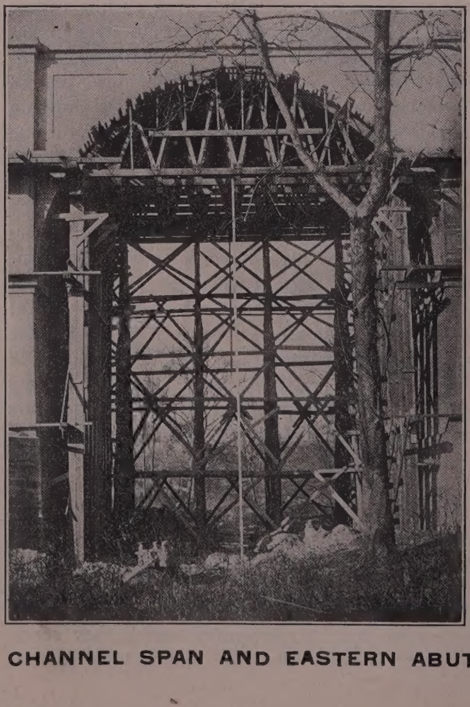
These joints provide for all temperature movements of the arches and are designed to prevent expansion cracks occurring in the masonry.

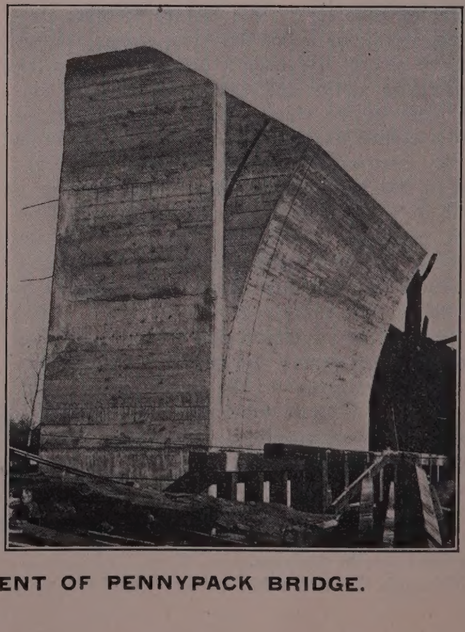
The joint in the horizontal coping slab is not provided with the tongue and groove, but is carried straight across the wall, and filled up to within 2 in. of the top with corrugated asbestos board above which there is placed a V-shaped sheet of ⅛-in. lead with horizontal flanges gained into slots in the top of the coping at their edges. This lead plate is covered to a depth of about ½ in. with asphaltic cement sufficiently plastic to elongate and contract with the slight temperature movements and always keep the lead covered and the joint closed. In order to assure a sliding joint without accidental bonding between the under side of the coping and the top of the spandrel wall, several thicknesses of felt are placed over the tongue and groove joint in the spandrel walls.

The specification called for two grades of concrete masonry: No. 1, made 1:2:4, and No. 2, made 1:3:6. The proportions of all materials to be determined by measurement. The volume of a barrel of cement, 375 lb., assumed to be 3½ cu. ft.

A one-pound sample was taken from each of five barrels, or bags in every car load lot of cement received, and chemical and physical tests made by the company's chemist. Upon the results of these tests depended the acceptance or rejection of the cement.







UMBRELLA FORM; A 60-FT. CHANNEL SPAN AND EASTERN ABUTMENT OF PENNYPACK BRIDGE.

The following brands of cement were used in the bridge, namely: Giant, Atlas, Vulcanite, Alpha and Dragon. About 60 per cent. of the cement used was Giant, the balance was pretty evenly distributed among the other brands.

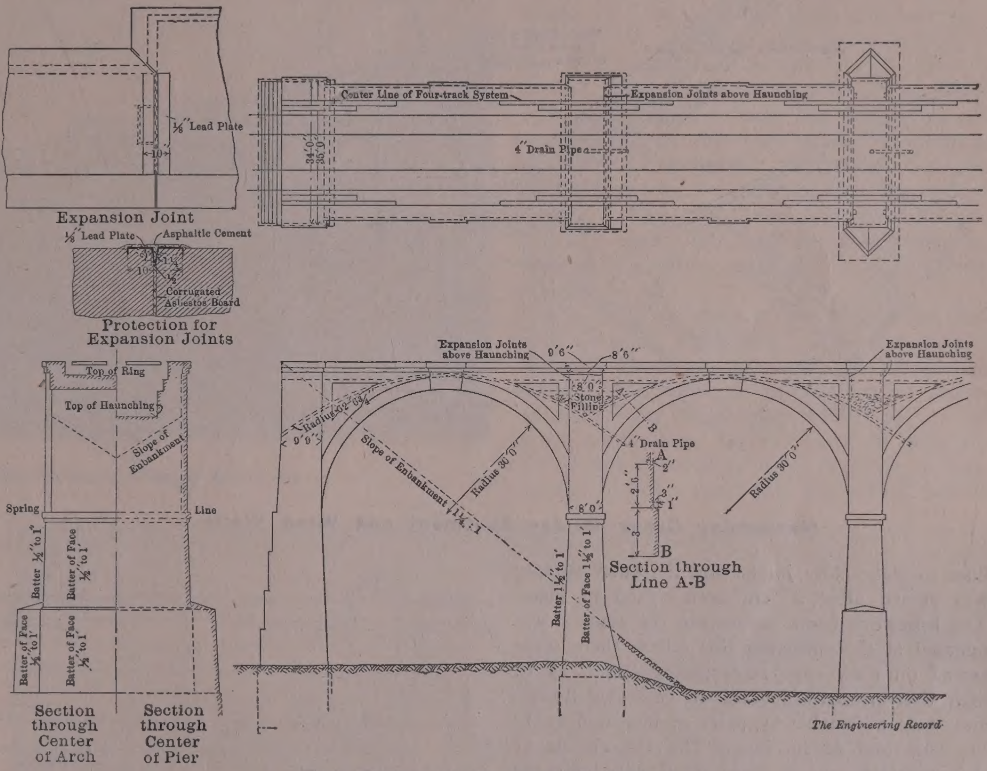
No. 2 concrete is used up to the springing line, above which No. 1 concrete is used for all parts of the structure. Broken stone of one-man size is used for filling above the haunches to subgrade where ordinary ballast is provided for the roadbed.

No serious difficulties were encountered in excavating for the foundations and bed rock was reached in every case. The greatest depth from the surface of ground to the rock was about 16 ft. Very little water was encountered in the foundation of the western abutment and pier No. 1. These were kept dry by a 2-in. steam siphon pump. A small cofferdam of single outside sheet piling was necessary at pier No. 2, which was kept dry by a 6-in. centrifugal pump. The season being a dry one the creek kept at a low stage and gave no trouble during the foundation work. At pier No. 3, the excavation was thrown up to form a dam which held the water back sufficiently, so that a 2-in. steam siphon kept the foundations dry.

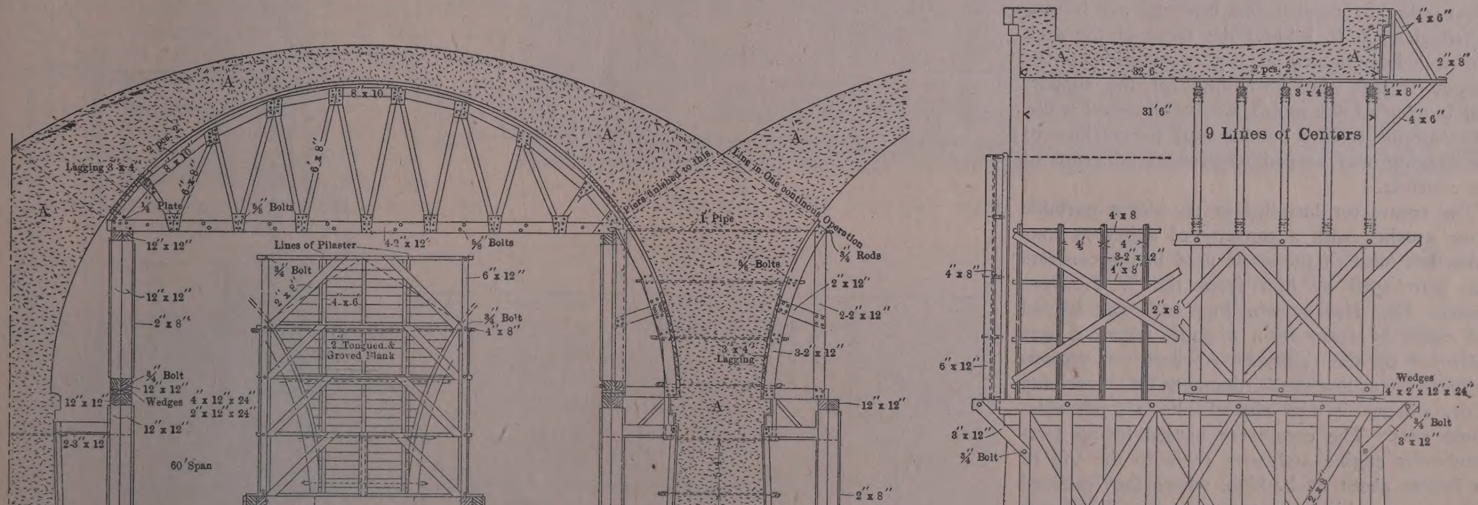
The foundations for pier No. 4 and the eastern abutment were very shallow, the bed rock rising rapidly with the surface. These conditions made the foundation work comparatively easy.

The piers were constructed in molds made with 2-in. tongue and groove horizontal plank planed on one side and secured by 4x6-in. vertical pieces and 4x8-in. horizontal rangers through which ¾-in. horizontal tension rods pass parallel to the bridge axis and afford reaction for the lateral pressure on both sides of the moulds. These rods had washer bearings at both ends and were protected from the concrete by 1-in. pipe which remained permanently in position after the rods were removed. On each side of each pier there was a double transverse bent of framed falsework made of 12x12-in. timber and 2x8-in. diagonals. These bents supported the main arch centers and the moulds for the lower parts of the arches which were built integral with the tops of the piers. These moulds were framed so that the external reaction was entirely vertical and they were supported wholly by the pier mould and the falsework. They were lined on the long sides with horizontal 3x4-in. lagging and at the ends with 2-in. tongue and groove plank and were called umbrella tops on account of their peculiar shape.

Between these molds the concrete was laid on trussed centers carefully fitted to the umbrella tops at both ends where they were supported on the falsework bents. The top chord was composed of one-panel lengths of 8x10-in. timber about 6 ft. long. Between panel points the center lines were chords of segments of a circular arc described with a radius a few inches less than that of the arch soffit. The bottom chord, 49 ft. long over all, was built up of four 2x12-in. planks with staggered joints, each of which was overlapped by three thicknesses of continuous plank. The web members were all 6x8-in. pieces with their ends beveled to abut with their full



End Spans of Pennypack Bridge.



Plan of Framing at Pilaster and Face of Arch

Plan of Framing at Piers

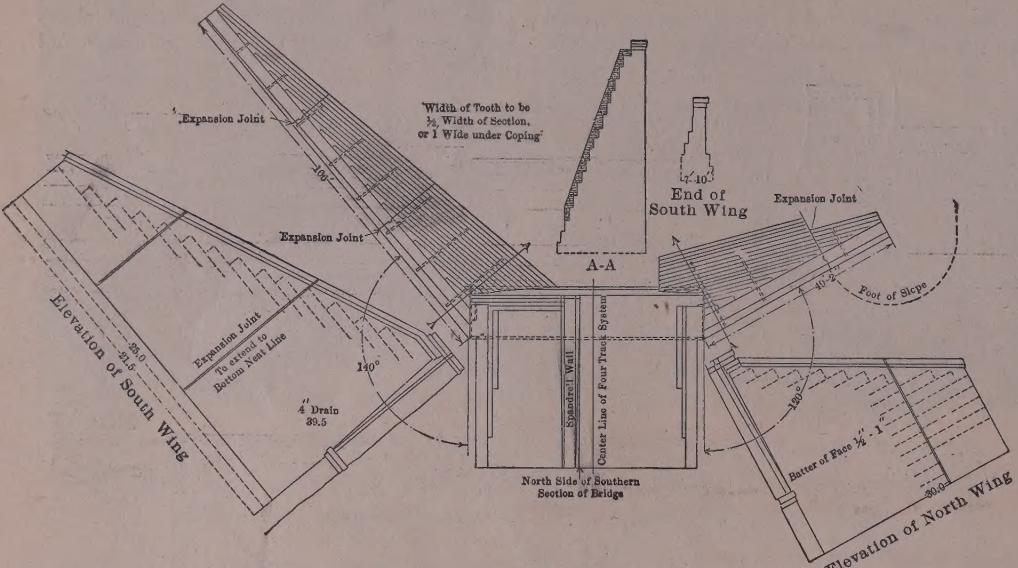
Channel Pier

Section at Crown of Arch

DESIGN AND CONSTRUCTION DETAILS OF PENNYPACK BRIDGE.

area against both chords, to which they were connected by ¼-in. cover plates and ⅝-in. bolts. The trestle, seen underneath the arch centre for the channel span in one of the accompanying illustrations, was independent of the latter and was built by the contractor for a service track during the construction of the bridge.

The top chord was covered with 3x4-in. lagging, the sides of which were planed on radial lines to make close joints, and the outer surface was planed after it had been nailed in place. The falsework bents supporting the centers terminated at the springing line where there were seated on their caps second-story bents, 15 ft. high, that in turn supported the centering trusses and were adjustable by pairs of oak wedges 12 in. wide and 24 in. long. The top chords of the centering trusses were fitted with pairs of 2-in. strips dressed to a circular curve on their upper edge to receive the lagging, which projected about 6 ft. beyond the faces of the arch and was knee-braced at the extremities to the outside trusses, thus providing for the support and bracing of the molds for the spandrel walls. The interior of the moulds and the surface of the lagging was soaped to prevent adhesion of the concrete.



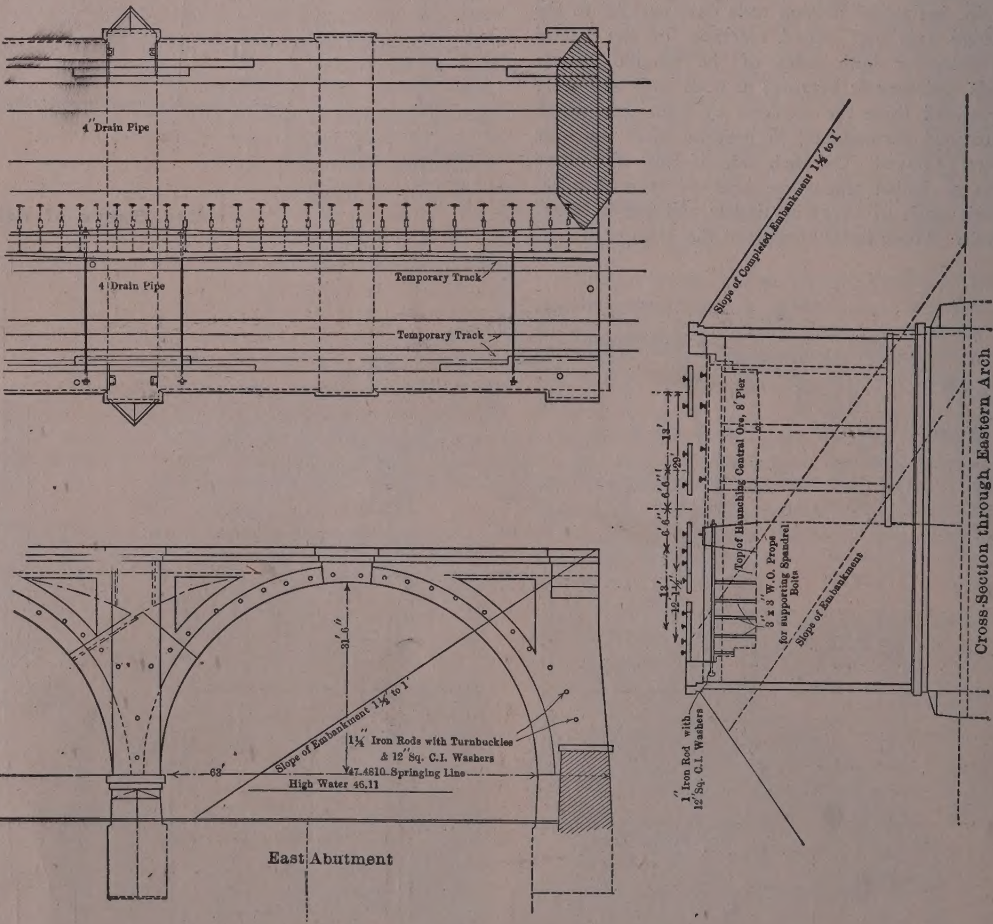
Neshaminy Creek Bridge Abutment and Wing Walls.

The contractor installed at the site a portable stone crusher with a capacity of about 75 tons daily, but most of the stone used in the concrete was purchased by him from the J. T. Dyer Quarry Co., Norristown, Pa., and was hauled 2½ miles by team from a point where it was delivered by the railroad. At first the wagons delivered it at low grade, dumping on a receiving floor, whence it was chuted into 1½-yd. side-dump cars. The cars were hauled by an Orr-Sembower engine and wire cable to the top of an incline about 25 ft. high, where they dumped into a storage bin of 50 tons capacity. Sand was handled the same way and stored in a 25-ton bin.

Later the cable incline was discontinued for all the materials except that produced by the portable stone crusher, and instead the wagons delivered them to a point on the grading about ¾ mile from the site of the bridge, where they were dumped into 1½-yd. side-dump cars and delivered by narrow-gauge train to storage bins on the grading just above the mixing plant. The materials were conveyed by long wooden chutes to the measuring hoppers.

This arrangement avoided a piece of bad road and was satisfactory, except that the inclination of the chutes was so small that it was necessary for men to work in them continually to keep materials moving.

Cement was stored at the top of the bluff where the sand and stone were handled and was chuted to the top of the storage bins where the bags were opened and the loose cement was chuted directly into the measuring hopper. The water of a small creek was impounded by an earth dam and piped about 600 ft. to the bridge site where it was used for general purposes and to fill a small tank on the concrete-mixing platform. The tank was gauged and valved so that a measured quantity of water, which could be varied according to the conditions, was used for each 1-yd. batch. The average product of the plant was 120 yd. in 10 hr. The mixing machine delivered directly into bottom-flap steel buckets handled to position and emptied in the molds by a 580-ft. Lambert cableway in the axis of the bridge. The cableway was supported on one 70-ft. and one 45-ft. tower, giving the loaded bucket a minimum clearance of 3 ft. above the highest point of the structure. This cableway was also used for handling the timber, falsework and centering trusses, the latter weighing 4 tons each and being assembled on the ground alongside the bridge within reach of the cableway hoist.


4" Drain Pipe
4" Drain Pipe
Temporary Track
Temporary Track
Slope of Completed Embankment 1½ to 1'
Cross-Section through Eastern Arch
13'
20'
6'-6"
6'-6"
13'
12'-1½"
Top of Haunching Central Ors. 8' Pier
3"x8" W.O. Props for supporting Spandrel Bolts
Slope of Embankment
1" Iron Rod with 12" Sq. C.I. Washers
31'-6"
Slope of Embankment 1½ to 1'
1¼" Iron Rods with Turnbuckles & 12" Sq. C.I. Washers
63'
47.4810 Springing Line
High Water 46.11
East Abutment

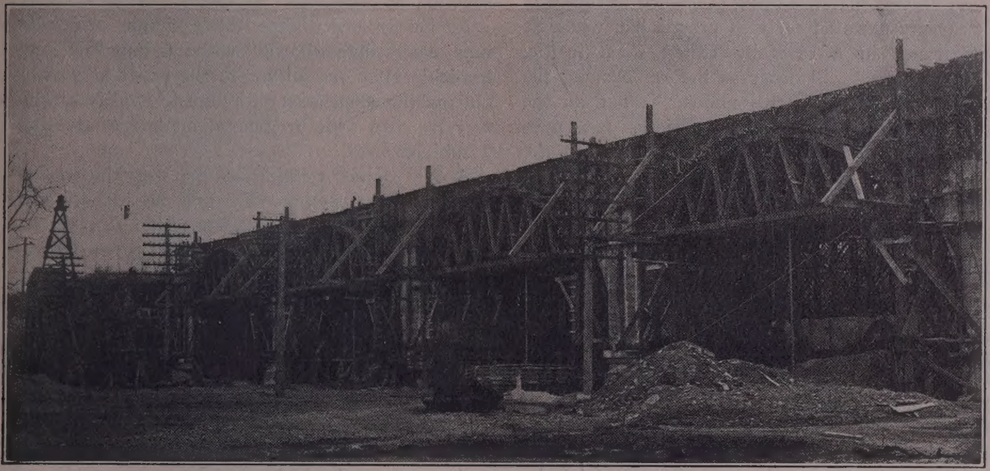
End Span of Neshaminy Creek Bridge.

The piers were built up to the springing line by successive day's work, thus giving an interval of 14 hr. between placing the different layers of concrete. Above the springing line, the concrete was filled in with continuous work averaging about 50 hr. up to the haunches, where it rose to a maximum height of 22 ft. above the springing line of the pier, sloping down from this point to the top of the umbrella molds on the dotted lines shown in the detail.

When the construction had been carried to this height on all of the piers and the centering for the arches was all in position, work was commenced simultaneously at both ends of every arch, and the concrete was built up both ways from the piers so as to maintain balanced thrusts on them. Between the skew-backs each arch was divided into seven transverse sections corresponding to large voussoirs, running through the full width of the bridge and keyed together by 4x10-in. horizontal transverse keys made by spiking planks to the center lines of the faces of the transverse bulkheads used to limit the sections. Each section of the arch ring was made simultaneously with that on the opposite side of the same, thus keeping a symmetrical and, as nearly as possible, uniform distributed load on the centers. After the completion of the arch rings, the spandrel walls were built and a settlement of about ½ in. was observed in the arches after keying. The centers were allowed to remain in position from 30 to 60 days after the arches were completed, and no settlement in the concrete was observed, after the centers have been struck.

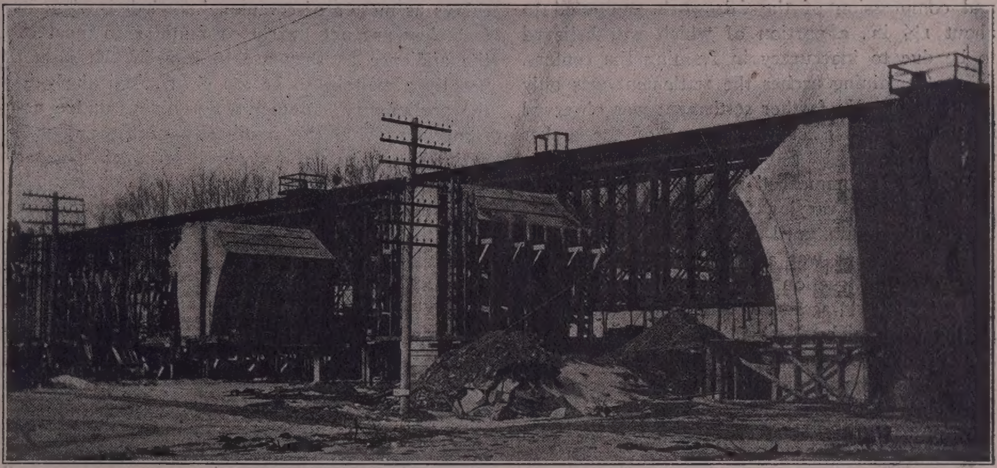
Excavation work was commenced in August, 1904, concreting was started September 23 of that year, and the bridge was completed ready for traffic September 23, 1905. The bridge was built with an average force of 75 men at a total cost of about $67,000. The contract was originally awarded to The Smith Construction Co., of Philadelphia, who commenced the work and were succeeded by The Kerbaugh Co., of Philadelphia, who completed the work.

The four-track bridge across Neshaminy Creek near Neshaminy Falls Station, on the main line of the New York division of the Philadelphia & Reading Ry., comprises two abutments with wing walls and five intermediate piers supporting five 65-ft. and one 52-ft. full-center arch spans. The general character and the details of the arches, expansion joints, piers, falsework, moulds and centering correspond with those described for the Pennypack Bridge, but the design and construction differ materially on account of the increased width of the bridge and the manner of erecting it.



Neshaminy Creek Bridge With Falsework and Cableway.

The bridge replaces a double-track bridge at the same site which consisted of seven spans of iron super-structure, two being of 60-ft. clear span and five of 150-ft. span. About one longitudinal half of the new super-structure was built alongside the old iron super-structure independently of it and without interrupting its traffic. After this was completed, the traffic was diverted from the old structure to tracks laid temporarily on the completed section of the new one, which was not of sufficient width to allow of the tracks being placed in their permanent position. A middle spandrel wall was built to maintain the stone filling for these tracks. The old iron super-structure was then removed and the second longitudinal half of the new bridge was built and thoroughly bonded with the old half, after which the two tracks were laid on it in their proper alignment, and the two tracks previously laid on the other side of the bridge were moved over to their permanent alignment, thus securing the completion of the new structure and the removal of the old one without interfering with the train service. The bridge was originally designed as a symmetrical structure with five 65-ft. spans flanked by a 52-ft. span at each end, without wing walls, but later developments caused this plan to be reconsidered, and one of the 52-ft. arches was eliminated, which made it necessary to build wing walls at the pier supporting the end of the 65-ft. span.

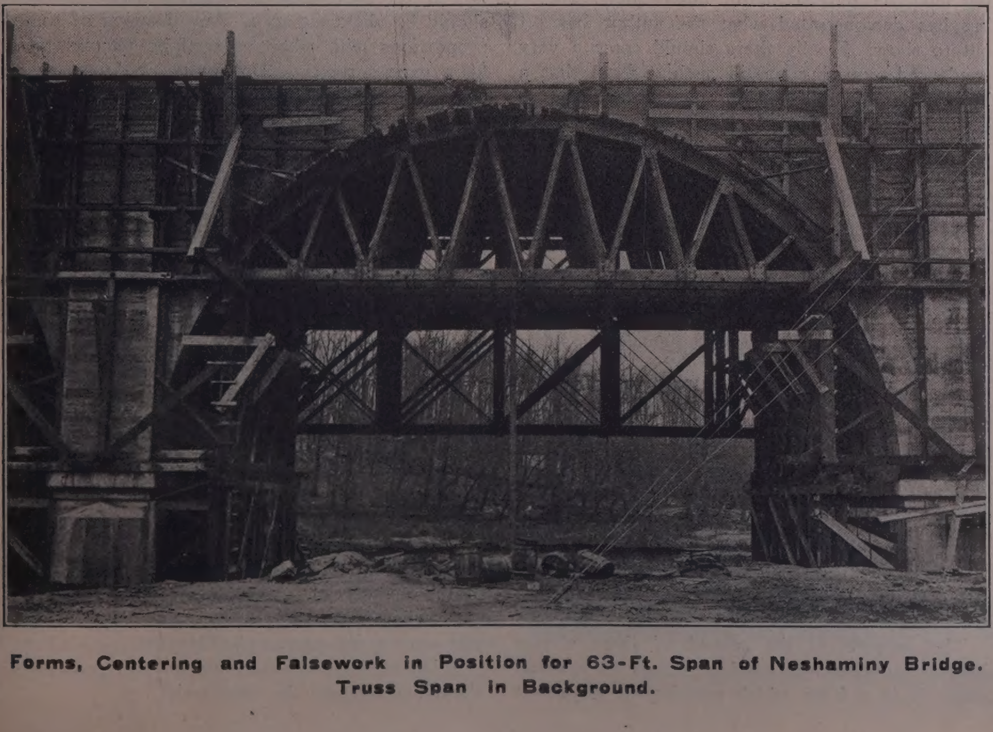


Building Piers for First Half of Neshaminy Creek Bridge.

Considerable difficulty was encountered with the foundations of the first section of the new bridge, on account of their depth and their proximity to the old piers. The greatest depth to bed rock was 48 ft. from the natural surface of ground, through wet clay, loose stone and gravel.

In nearly every instance the foundations for the piers of the first new section were carried down below those of the old structure, and great care was necessary to prevent these latter from settling. Some slight movement of the tracks over one of the piers was noted while the excavation was being made, but nothing serious came of it.

This work was done in open excavations made with sheet-pile cofferdams. The upper part of the cofferdams were built with 3-in. square edge wooden sheet piles 16 ft. long, braced against 9x12-in. waling pieces from 3 to 6 ft. apart. The earth inside them was excavated by pick and shovel and removed by boom derricks. A large amount of water which was encountered was removed by 6-in. pulsometers and by centrifugal pumps, four of which with discharges of 4 to 6 in. being sometimes necessary in a single excavation. After the first course of sheeting was driven it was followed by a second and third course of the same character, all sharpened to a wedge point at the bottom and driven by hand as the excavation continued. The surface of the rock was found to be very irregular with the strata dipping in different directions, sometimes nearly vertical. It was excavated to sound material, thoroughly cleaned and the pit was filled with a solid mass of concrete deposited in molds, the cross struts being removed to clear the concrete as the latter advanced.



Forms, Centering and Falsework in Position for 63-Ft. Span of Neshaminy Bridge. Truss Span in Background.

Broken stone and sand were delivered both by railroad cars and by wagons, and were stored in piles on platforms from which they were delivered by wheelbarrows to a Ransome concrete mixer near the water level. The concrete mixer discharged into 1-yd., bottom-flap steep buckets, which were handled at the rate of about 180 in 10 hr. by a 500-ft. Lidgerwood cableway erected successively in two positions on the center longitudinal lines of the halves of the bridge. Horizontal steel rods 1¼ in. square and 8 ft. long were built into the first half of the arch ring in the positions indicated by the small circles in the accompanying elevation and projected 4 ft. beyond the temporary face of the concrete to engage the second half of the superstructure. They were anchored with 8x8-in., cast-iron reaction plates at each end and were provided with turn-buckles in the middle, as only one-half could be placed before the old truss bridge was removed.

As soon as traffic was placed on the first section of the new bridge, the old trusses were dismantled and scrapped, and the work of tearing down the old piers begun. These were entirely removed and, where necessary, the excavation was carried still further until the bed rock was reached. The rock was not nearly so deep under the second half of the bridge as under the first half, and no serious difficulties were encountered in the foundation excavation.

In the construction of the first half each alternate pier had been completed to the springing line for the entire width of the bridge, so that at this stage only about half of the pier work remained to be done.

Upon completion of the piers and "umbrella" forms for the second section the main arch centers, which had been used for the first half, were lowered on 12-in. wooden rollers and moved bodily, with the lagging, into position for the second half of the arches.

The 21,000 cu. yd. of concrete were made principally with Portland cement, and in the same proportions as for the Pennypack bridge. When the first arch was keyed a combined settlement and compression of the falsework amounted to about 1½ in., a portion of which was believed to be due to inaccuracy in framing the centers. In the remaining arches the settlement was only about ¾ in. No farther settlement was observed in the concrete after the centres of the arches were struck.

Work was commenced in May, 1904, and carried on with a varying force of about 100 men at the maximum until its completion in April, 1906. The work was awarded to the Millard & McGraw Construction Co., of Philadelphia, Mr. J. D. Kilpatrick, secretary, being in direct charge of the work. The Neshaminy Creek bridge and the Pennypack bridge were designed and their construction was directed by the engineering department of the Philadelphia & Reading R. R., Mr. Wm. Hunter, chief engineer.

The Metal Cross Ties that were placed in the track of the Bessemer & Lake Erie R. R. in November and December, 1904, and January, 1905, have given satisfactory results during the time they have been in service. These ties are of the Carnegie I-beam type and replaced white oak ties in a section of track on a curve laid with 100-lb. rails and ballasted with 6 to 8 in. of slag, 1,000 of the steel ties being put in. Although the space occupied by the steel ties is smaller than that occupied by the wooden ones, additional ballast was not furnished, so there was not sufficient ballast to half fill the track From November, 1904, to June, 1905, there was a single track only at this point, so all of the traffic of the road passed over the steel ties. The experience obtained with these ties was given before the Railway Club of Pittsburg by Mr. H. T. Porter, chief engineer of the Bessemer & Lake R. R., who said that up to the present time only one rail had been broken on the steel ties and that break was reported to be due to a flaw in the rail. Where the steel ties have been used there is less wear on the rails and the wear is more uniform than where wooden ties are used. These ties have not been used long enough, Mr. Porter said, to determine their life under the conditions, but a tie broken after six years of service does not indicate that rusting under ordinary conditions should cause anxiety.

Suggestions for Authors of Engineering Papers.

One of the indications of increased activity evinced by the American Society of Mechanical Engineers is the appearance of the first number of its "proceedings," which is to be issued monthly except during July and August. It will contain advance copies of all papers and unrevised reports of all discussions at Society meetings; all this material being published in this way as Society news as early as practicable, while its appearance in a carefully edited form in the "Transactions" will occur as before. Among the salutatory articles in this number is one on the preparation of papers for the Society. It is published as a tentative draft, in the hope that the members will make further suggestions, and is reprinted here as of general interest to the many engineers inclined to give the public the benefit of their experience or study, but at a loss how to do it. The suggestions read as follows:

In preparing a paper for presentation before a professional society, or for publication, there are some general principles, the observance of which will add greatly to the value of the work. These principles do not relate to the subject matter directly, but rather to the manner of presentation. In the first place, a paper should, and generally does, relate to some especial department of work with which the author has had experience, so that he is very apt to assume many things as matter of common knowledge, when in fact they are not nearly so familiar to most of the audience as they are to himself. It is not usually a mistake to be too clear, particularly in the preliminary statements. Avoiding undue assumptions as to the familiarity of the audience with the subject, the general form of a paper should be about as follows:

State first, in a brief and clear manner, just what the paper is about, what the author is endeavoring to show, or what he expects to prove. This introductory statement should be very brief, and having been made it should be kept in mind throughout. A paper should be about but one thing at a time, and that one thing plainly stated at the start. Then should follow the general treatment; description of work, of experiments, of opinion, etc., this portion constituting the matter usually forming the body of technical articles or papers. After this should come what may be called "proof," that is, a statement showing how the general matter immediately preceding has demonstrated what the author has set out to show. Finally there should come a very condensed summing up, in such a form that a brief glance would enable a casual reader to grasp the substance of the paper, and decide without reading the whole, whether or not he wants to examine it in detail.

The introductory statement, and the final conclusions, should in every case enable the reader to get at the kernel of the whole matter, of which the bulk of the paper should be the detailed and expanded treatment.

The use of tables should be avoided whenever it is practicable to present results in a summarized form and where the tables do not make in themselves a distinct addition to the value of the paper.

Papers may be divided into two classes: those which give a record of experience or investigation in a formal manner, presented mainly for the purpose of putting the subject upon the official record; and those intended to arouse discussion, and presented for the very purpose of eliciting the opinions and experience of members at the meeting.

The purpose of the second of these classes cannot be successfully attained unless the original paper is in a form which permits the argument to be readily grasped. Many members do not have the opportunity of examining the paper until a few minutes before it is presented, and yet these should be able by a glance at the introduction and the conclusion, to decide whether it is a subject which they can discuss. Results of investigation are sometimes given in final form only, as tables or plotted curves, and while these are both most desirable, there should always be a general summing up of the leading results of importance in plain language, for immediate absorption by any one.

In nearly every case these simple principles may easily be followed without imposing any hardship upon the author of the paper and without making it necessary for him to modify in any way his own style or general method of treating a subject.

A few points relating to the reproduction of papers in the printing office may be added, as of much importance to the Publication Committee.

Write plainly on one side of the paper. Number the sheets consecutively in the upper right hand corner and have them of a uniform size. A good size is 8½ x 11. It is desirable to have manuscript typewritten when this can be done without undue inconvenience. Give dimensions, etc., in the English system. If desirable the metric equivalents can be bracketed.

Put your full name and address on all manuscripts. Copy should be sent flat, never rolled and preferably not even folded. Never fold illustrations intended for reproduction. Tracings may be sent rolled in mailing tubes.

All diagrams, drawings, etc., should be made on separate sheets of paper and if possible so as to bear photographic reduction to the standard page size of the "Transactions." Photo-engraving is reliable and accurate, and greatly to be preferred to any process which requires the illustration or diagram to be redrawn. Good tracings can always be reproduced, but the reduction should not have to be more than one-third, preferably one-half, the linear dimensions of the original. Since the width of the type measure of the page is 4⅛ in. a drawing to be reduced to page-width should not be more than 8 to 12 in. wide.

In making drawings intended for reproduction it is well to exaggerate the size of all numerals and dimensions so that under reproduction on a reduced scale they will still be legible. The greater the reduction the heavier should be the lines to give sharp results. As the height of the page is 7 in. the proportion of height to width in copy should be about 1.7 to 1. Any drawing of these proportions will, when reduced by photography, fill a page correctly. Do not use red ink, as it does not reproduce.

In selecting photographs or making photographic prints for illustrations, it should be remembered that the glossy solio prints are better suited for reproduction than velox or other matte surface paper, besides bringing out all the detail in the negative to the best advantage. Photographs should not be printed too deep, and the reproductions are better made from prints of a slightly reddish tone than from those over-toned to a bluish tint.

All copy intended for illustrations should be clearly marked with the title, subject and author's name, a reference to the manuscript to which it relates, and all other data of interest. This had better be written on the back in pencil; ink is apt to show through, especially when written on the back of light portions of a photograph.

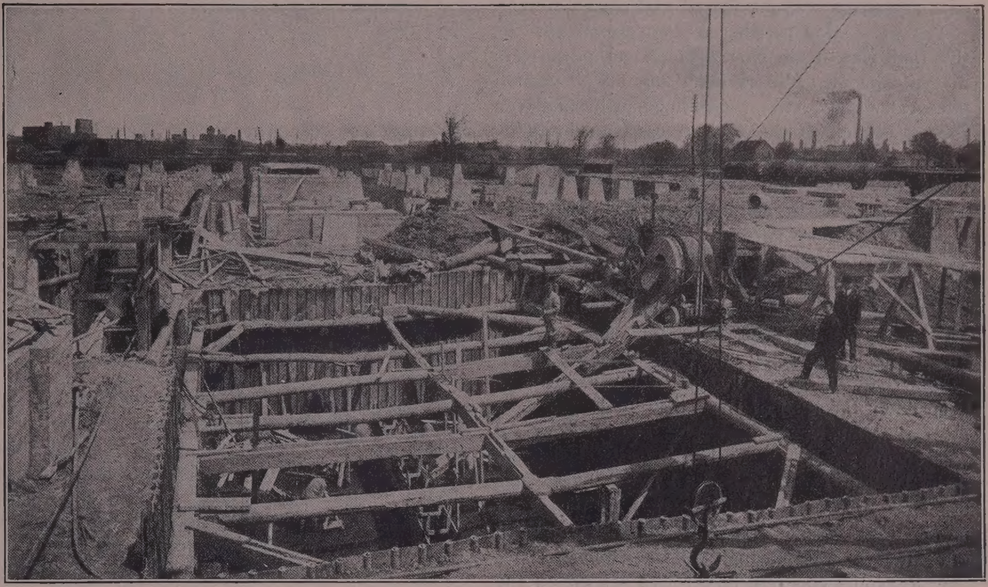
The places where plates and figure references are to be inserted in the text should be indicated in the manuscript. Illustrations should only be used where necessary for the elucidation of the text—never for mere embellishment.

A list of illustrations giving their titles in brief should accompany the manuscript.

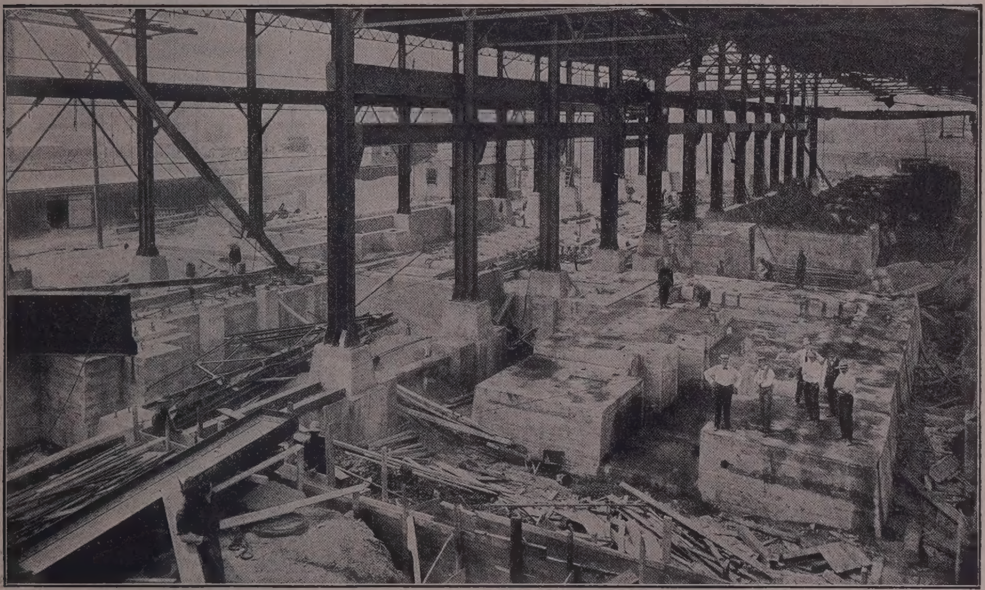
Steel Sheet Piling for Large Engine Foundations.

Steel sheet piling has recently been used to advantage in constructing in particularly bad soil the foundations for a 48 x 60-in. engine in the plant of the New York State Steel Co. at Buffalo, N. Y. This plant is in the southern part of the city adjacent to the Buffalo plants of the Lackawanna Steel Co., the Buffalo & Susquehanna Iron Co. and a number of other large manufacturing concerns. The location of these plants is well adapted to their economical operation, but the sites on which the plants have been erected afford poor foundations for the proper installation of the heavy machinery equipment required in them.

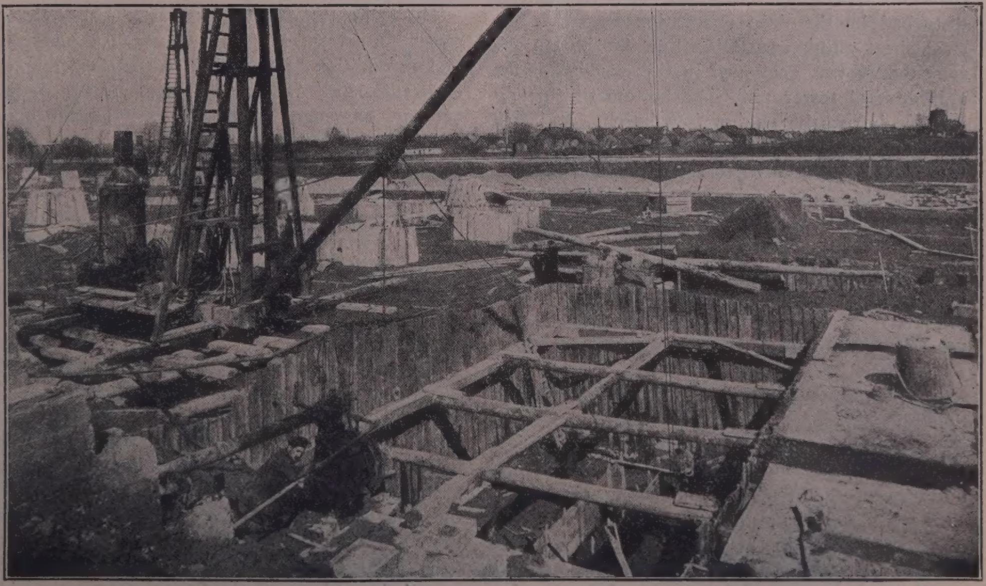
The plant of the Lackawanna Steel Co., which was described in detail in The Engineering Record shortly after it was completed, is on a site on the shore of Lake Erie that was originally almost entirely swamp land or low meadows, having varying depths of decayed vegetable matter at the surface, with underlying strata of quicksand and clay. The foundations for a 55 x 60-in. engine driving a 48-in. universal rolling mill, and for a 48 x 60-in. engine driving a 32-in. slabbing mill in this plant rest on a dense strata of hardpan overlying rock. The excavations for these foundations were carried to a depth of 32 ft., and were made with difficulty. The rock lies within 10 ft. of the surface under a portion of the site of the plant of the Buffalo & Susquehanna Iron Co., which immediately adjoins the Lackawanna Steel Co.'s plant, so that the construction of the foundations for this plant were carried on more readily.


Placing Tunnel Forms in the Engine Foundation Excavation.

The plant of the New York State Steel Co. is on the Buffalo River, northeast of the two plants mentioned. The soil conditions encountered in the construction of this plant were practically the same as those met with when the plant of the Lackawanna Steel Co. was built, except that considerable water had to be handled in the excavations for the new plant, a difficulty from which the work on the older plant was practically free. The ground surface at the plant of the New York State Steel Co. is about 10 ft. above that of the ground at the Lackawanna Steel Co. and the top soil at the site of the former plant is much better, consisting of 8 to 12 ft. of firm yellow clay. This clay, however, ran out at the point where the 48 x 60-in. engine and the 36-in. blooming mill, which it drives, are placed. Hardpan lies at a depth of 60 ft. at the site of this engine and its mill and is overlaid by 40 ft. of blue clay. Between this blue clay and the surface were encountered various soils in the following order from the surface down: 5 ft. of yellow clay, 4 ft. of swamp soil, 2 ft. of black muck, 4½ ft. of quicksand and 5½ ft. of gravel. The stratum of gravel, although firm, admits water freely in places and is believed to be an old river bottom. The depth at which the hardpan occurs made impracticable an excavation carried down to it for masonry foundation for the engine and mill. The decision was therefore made to carry an excavation down to a depth of 18 ft. so that it would end in the stratum of gravel, then drive piles 4 ft. apart on centers in both directions and lay the concrete of the bottom of the foundation which was to carry the engine and mill around the heads of these piles.


The Completed Foundation.

Inasmuch as the 4½ ft. layer of quicksand had to be passed through in making the excavation it was necessary to make provisions to hold back the sand and water. The large cross-section of the excavation made these provisions more difficult and necessitated the use of some form of sheeting that would preserve the alignment of the sides of the excavation. The desire to carry on the construction of the engine and mill foundation separately also required that the sheeting used must be of such design and of sufficient strength to permit it to be driven, drawn and re-


Excavation for Mill Foundation Showing Pile Driver and Pump.

driven. The standard section of steel sheet piling, manufactured by the United States Steel Piling Co., was considered to answer all of the requirements, so a proper amount of steel piling of that section was purchased and used.

The excavation for the concrete foundation for the mill was made first. The steel piles were driven with an ordinary drop hammer on a land pile-driver rig. After the piling had been driven the excavation of the core of earth enclosed by the four sides of the rectangle in which the piling was driven was started, a boom placed on the pile-driver rig handling the excavated material. When the excavation had reached a depth of 4 ft. heavy timber rangers were placed against the piling around the four sides of the pit and braced against each other by transverse and longitudinal struts, as shown in the accompanying illustrations. A small centrifugal pump placed at one end of the excavation was sufficient to keep down the level of the water in the pit. The flow of water was considerable after the gravel was encountered, originating in several distinct springs. The water was piped from the springs to a sump in which the suction of the small pump was placed. These pipes were plugged after the concrete laying had commenced.

A Ransome concrete mixer was set up on the ground along one side of the excavation and the concrete discharged from it through a chute into the pit until the level of the concrete had been brought up nearly to the ground level. In order to prevent the concrete from becoming bonded to the piling 3-ply tar paper was placed along the latter as the level of the concrete rose. When the concrete reached the surface a few changes were made in the rigging of the pile driver and the piling drawn with the latter. Although the head block usually employed in driving these steel sheet piles had been omitted the piles were found to be practically as good as new when drawn and were driven for the excavation for the engine foundation, the work on which was carried on in the same manner.

Recesses were left in such position in the face of the mill foundation on the side adjoining the engine foundation, that when the concrete of the latter was laid the two foundations were thoroughly keyed together. The engine foundation required the construction of three tunnels from which bolt alleys lead, as compared with a single tunnel in the mill foundation, so that the concrete work of the former foundation was correspondingly more difficult.

The completed foundation for the engine and mill required 2,000 cu. yd. of excavation and 3,300 cu. yd. of concrete. The adjoining foundations for heavy steel columns were in no way disturbed by the deep excavation in which the steel sheet piling was used. For this reason the same piling was employed in the excavation for a large coal tower pit. The bottom of this pit is 2 ft. below the engine foundation. It has a floor and walls 3 ft. thick. This concrete work was placed and allowed to set without losing any cement, although a 6-in. centrifugal pump had to be kept in service to keep the water down.

The foundation work was designed and supervised by Mr. R. R. Hillman, superintendent of construction for the New York State Steel Co. Messrs. A. F. Chapman & Co., of Buffalo, N. Y., were the contractors.

The Kansas-Colorado Litigation relating to the utilization of the Arkansas River in the two States will not be taken under consideration immediately by the Supreme Court. The great importance of the case, in establishing precedents concerning questions of interstate water rights of direct concern to the people of half the country, has led to postponing its consideration until a full bench is secured by the appointment of a successor to Justice Brown.

The New Plans for the Washington, Baltimore & Annapolis Railway.

Some three years ago the plans of the people then interested in the Washington, Baltimore and Annapolis Railway attracted widespread attention among engineers and railway officials because they were the first to select single-phase equipment for an interurban undertaking. The discussions of the technical features of the project contain some valuable contributions to electrical literature, but these plans were never carried out on account of the difficulties of financing the road. The project has lately been taken up again, and the judgment of the original engineering staff in selecting single-phase motors has been confirmed by a second decision to use such equipment, although it is of far different design.

In the former plans for single-phase equipment between Baltimore and Washington it was proposed to use a trolley potential of 1,000 volts, current being delivered at this voltage at a frequency of 16 2-3 cycles per second. The present contract calls for a trolley potential of 6,600 volts at a frequency of 25 cycles per second. On the cars a four-motor equipment was proposed, each motor having a capacity of 100 h.p. The new car equipments will consist of quadruple motor equipments for direct or alternating currents, each motor having a capacity of 125 h.-p. While the first proposed motor equipments would have driven the cars at about forty miles per hour, the new equipments, totaling 500 h.-p., will enable express trains on the road to attain a speed on tangent level track of 60 miles per hour.

The details of the new road have been worked out by the Roberts & Abbot Engineering Co., of Cleveland, Ohio. Single-phase equipment was chosen only after thorough study had made it apparent that this system would prove most economical and best adapted to meet the special service conditions existing on this road. Some sixty miles of road will be operated by the new company. The main line will be constructed between Baltimore and Washington, with a branch line extending to Annapolis from a point on the main line near Odenton. This station on the new line will be known as Academy Junction. Over the main line between Baltimore and Washington an express and local service will be established, express cars being operated under a fifteen minute headway and making the run in 72 minutes. The roadbed will be double-tracked throughout, with sidings arranged at suitable intervals so that the locals may be sidetracked to enable the expresses to maintain schedules.

The rolling stock equipment is to be very complete. Nineteen express cars will be operated, and in addition two work-cars will be equipped, each sufficiently powerful to haul a train of five ordinary passenger coaches at 45 miles per hour, while four lower-powered cars will be used for local service. These last mentioned cars will run at a speed of 45 miles per hour. The express and work-cars will each be fitted with four 125-h.-p. alternating-direct current motor equipments, with the Sprague-General Electrict train control. The local cars will be similarly controlled but will be driven by two instead of four GEA-603 motors.

Power for the new road will be purchased from the Potomac Electric Co. at Washington, D. C., and will be delivered by that company at 6,600 volts, three-phase, to a transformer substation located about three miles from Chesapeake Junction. In order to obtain a balanced load on the three-phase generators, the current as received at the substation will be changed from three-phase to two-phase by groups of two transformers connected three-phase on the 6,600 volt primary side and two-phase on the secondary side. Half of the transformers will have the secondaries wound for 6,600 volts and the other half for 33,000 volts. The 6,600-volt windings will all be connected in parallel on the same phase supplying single-phase current to the trolley as far as Academy Junction. The 33,000-volt secondary windings will all be connected in multiple on the second phase to the 33,000-volt transmission line which will supply current to a stepdown substantion at Academy Junction. The Chesapeake Junction substation will contain seven 800-kw. water-cooled transformers, three with 33,000-volt secondaries and four with 6,600-volt secondaries, one of the latter transformers forming a reserve.

At Academy Junction there will be four water-cooled transformers, 25-cycle, 800-kw., reducing the single-phase 33,000-volt current of the transmission line to 6,600-volt current suitable for delivery to the cars. These transformers will supply the Baltimore and the Annapolis sections of the line.

The sub-station at Academy Junction will be located adjacent to the car barns. For greater safety in inspecting and handling the cars, all of the trolley circuits in the car barn will be arranged for 600-volt direct current, and for this purpose two 300-kw. motor-generator sets will be installed in the transformer substation changing the 6,600-volt alternating current to 600-volt direct current. The motor end of these motor-generator sets will be connected direct to the trolley circuits, one phase being led from the trolley coming from Chesapeake Junction and the other from the Academy Junction transformers. A feeder regulator will be placed in one phase so that the motor-generator sets will act as balancers, permitting the Academy Junction transformers connected on phase B to feed into the trolley line supplied by the Chesapeake Junction transformers on phase A. In addition to acting as balancers and to supplying current to the cars in the barns, the motor-generator sets will also supply direct current to the motors in the repair shops located at this point.

Government regulations within the District of Columbia prohibit the use of the track return, so that within this section the cars will be operated with a double trolley. This portion of the tracks, as well as that within the city of Baltimore, is at present operated by direct current, and the new cars are designed to operate on direct current over these sections of the line.

The present Washington, Baltimore & Annapolis Railway Co., which is constructing the line, is quite distinct from the initial corporation. The new company, under the head of its president, Mr. Geo. C. Bishop, has considerably broadened the former plans. Land has been purchased for a wider right-of-way along the route, and new bridges are being built, so that the roadbed will be excellent. The engineering work is in charge of the Roberts & Abbot Engineering Co. of Cleveland, Ohio, and contracts have been placed with the General Electric Co. for the complete electrical equipment. The construction and operation of this road will be watched with great interest, as it is one of the largest and most important installations of the single-phase railway system ever undertaken.

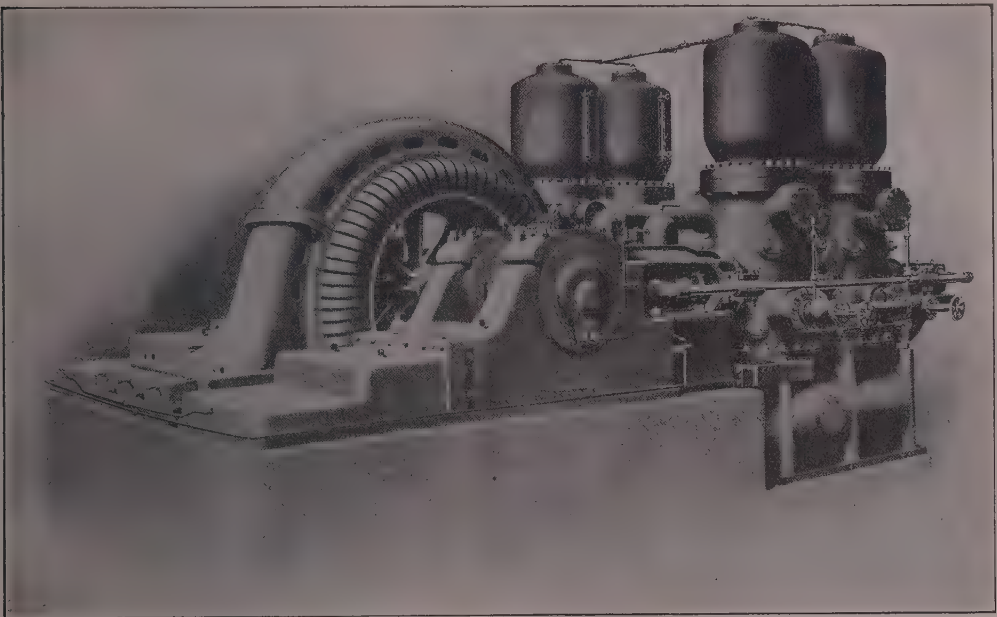
The Battleship, "Dreadnought," the turbine-driven vessel recently added to the British navy, has completed her power trials under service conditions. These are understood to have been highly successful, although the official details are withheld. It has been unofficially stated that she steamed for eight hours at an average speed of 21.5 knots and a maximum speed of 22.4 knots, indicating that she is the fastest ship of her class ever built. The run was made with the ship carrying the equivalent of a sea-going load. The turbines are stated to have run very smoothly.

Electrical Mine Pumps at the Ward Shaft, Virginia City.

By Leon M. Hall.

The pumping plant just received at the Ward Shaft, Virginia City, Nev., is probably the largest, best and most complete electrically-driven mine pumping installation ever constructed, so that a brief description of it, with the reasons for its existence, may be of interest to those engaged in the mining and electrical industry. The Ward Shaft Association was formed some three years ago for the purpose of opening the Ward Shaft and draining the middle group of mines on the Comstock, in order to explore this lode to its very lowest depths. This shaft was originally sunk to a vertical depth of 2,480 ft. and just before reaching this point passed through the vein, which proved to be a mineralized fissure over 60 ft. in width. Some fifteen years ago, this shaft was abandoned on account of the stagnation then existing in the silver market and, with the cessation of work, it was allowed to decay and partially fill with rock and refuse of all kinds.

The shaft was rehabilitated and re-timbered without much trouble to the 1,600-ft. level, at which point a drainage drift was run 275 ft. to connect with the south lateral branch of the Sutro tunnel. Below this level difficulties of all kinds incident to hot water and its attending evils were encountered and the progress has consequently been slow and expensive. To-day the shaft is in perfect condition to the 2,430-ft. level, leaving but 50 ft. of the old shaft to recover. From the 2,480 to the 3,100-ft. level the work will all be in new ground, probably free from water, so that it is confidently expected that progress will be rapid and the new electric pumps put in early operation. In reopening this shaft, a considerable flow of very hot water was encountered so that quite an extensive temporary pumping plant was necessary.



Electric Pump Delivering 1,600 Gal. per Minute against 1,550 Ft. Head.

On the 2,100-ft. level a 6¾ x 8-in. Knowles vertical triplex pump, geared to a 100-h.p. type C Westinghouse induction motor, was placed. This takes its water from a three-step Byron Jackson centrifugal pump belted to a 50-h.p. Westinghouse induction motor, located on the 2,330-ft. level. In turn, this centrifugal pump receives its supply from a 9-in. Blake sinking pump at the bottom of the shaft. Two 100-h.p. Ingersoll-Sergeant compound air compressors driven by two 100-h.p. Westinghouse motors are in operation on the surface and supply this sinker with the necessary motive power. This temporary plant is raising 300 gal. per minute 855 ft., from the present sump to the Sutro tunnel level.

In order to supplement this plant, a five-step Byron Jackson centrifugal pump, directly connected to a special Westinghouse induction motor, has been installed on the 2,410-ft. level. This pump has a capacity of 600 gal. per minute against a head of 900 ft., and it will take its supply of water directly from the sinking pump, thereby doing away with the triplex and centrifugal pumps before mentioned. This pump is entirely of bronze, operates at 1,700 r.p.m. and under these conditions shows an efficiency of 67 per cent. with the water temperature 160° Fahr. This pump will be duplicated immediately for safety of operation, and, with these as an auxiliary, the company confidently hopes to reach the 3,100-ft. level at no distant day.

On the 3,100-ft. level the excavation of a pump station 80 ft. long, 24 ft. wide and 20 ft. high is contemplated, in which will be placed the permanent pumping plant, the subject of this sketch. The capacity of this permanent installation will be 3,200 gal. per minute against a total head of 1,550 ft., and this will be divided between two units each separately driven by a special slow-speed 800-h.p. Westinghouse induction motor. The pumps are of the Knowles express type. They are outside end-packed duplex double-acting pumps with plungers 6 11-16 in. in diameter and 15-in. stroke. The rotating element of the motor is placed directly on the crank shaft and they will operate at 195 r.p.m.

The valves are automatic poppet valves arranged in nests of 13 each. The valve area, 103.35 sq. in., is unusually large so that the consequent movement of the valves is extremely small, all of which is conducive to a high rotative speed with a minimum of wear. The valves, stuffing-box glands and other vital parts exposed to the action of the water are of bronze and are arranged so that they may be readily renewed.

The plant will be equipped with a three-stage electrically-driven air compressor for charging the air receivers, a vacuum pump and an automatic oiling system. For convenience of erection and repair, the pump station will be fitted with a 15-ton traveling crane; in fact, it is intended to include in this plant everything that will insure reliability and ease of operation.

The over-all dimensions of each pump are 27 ft. 3¾ in. in length, 17 ft. in width and 14 ft. 2½ in. in height. The motor is 13 ft. in diameter and the steel crank shaft, forged from one piece, is 13¾ in. in diameter and 14 ft. 4½ in. long. The total cost complete for operation will be about $125,000. These pumps will be supplied by either one of the two centrifugals located in the sump at the bottom of the shaft and operated by special 75-h.-p. Westinghouse motors on a vertical shaft.

The water will be discharged through a 16-in. O. D. steel pipe with welded steel flanges. The thickness of this pipe varies from ¼-in. at the tunnel level to 9/16 in. at the bottom. It will be supported by means of heavy iron clamps 6 in. in length, which, in turn, will rest upon the wall and end plates. To resist the pressure of 675 lb. to the square inch, male and female flanges are used and each fitted with a lead-filled copper gasket. The electric current is taken down the shaft at 2,240 volts over a three-conductor lead-covered steel-armored cable of 400,000 cm. capacity.

Concrete Tile Culverts in Ontario.

The use of concrete tile for small highway culverts in Ontario is steadily increasing, and where they have been properly made there is rarely any complaint against them, according to a special report of Mr. A. W. Campbell, commissioner of highways of the Province. In some municipalities they have been in use fifteen to eighteen years without renewal, and still appear to be as good as when first laid.

Among the chief points to observe in making them, Mr. Campbell states, are that they shall be made of good materials, the concrete carefully mixed, and that they are not too small. The size is controlled to some extent by the depth of the side drains below the graded roadway, as it is necessary that there should be a foot of earth over the pipe. It is not desirable to use pipe less than 18 in. in diameter if the situation will permit; but two smaller lines of pipe may, as an alternative, be laid side by side. The objection to small pipe is that they are liable to be stopped up. In striving to keep down expense, there is a tendency to use concrete tile where a large waterway is needed. This is the reverse of economy, for by contracting the water area, drainage is impeded, the road-bed is injured, and washouts frequently result. Concrete tile are excellent in their place, where they give sufficient waterway, but provisions should always be made for the maximum rushes of water, not the average flow. Where concrete tile are too small for this, concrete arches, or square top culverts should be considered.

The construction and repair of wooden culverts has become, in numerous townships, a serious drain upon the yearly appropriation available for road purposes. In some cases Mr. Campbell finds that as much as half or two-thirds of the grant from the general funds is absorbed in this way, a matter of from $1,000 to $2,000 annually. The number of these culverts on country roads varies greatly. Ordinarily half a dozen are needed for each mile of road if proper drainage is provided. By replacing these, as required, with permanent concrete culverts, this annual expenditure can be almost wholly wiped out.

Making concrete tile for culverts is not a difficult matter, and can be undertaken by the municipalities themselves, although in numerous cases they are now manufactured as a private enterprise. Just such a number of pipe as are actually required for the season's work need be manufactured; the implements required are inexpensive, and the pipe may be made by the municipality for actual cost, which, after a little experience, can be reduced to a very small amount. The outfit required consists of two cylinders; the larger hinged, the smaller a spring cylinder; bottom and top rings; and a tamping iron. The one cylinder forming a core, sets inside the other, leaving a space between the two equal to the thickness of the finished concrete pipe. These can be procured from the manufacturers of roadmaking machinery. By a "spring cylinder" is meant one formed by rolling a steel plate into a tube without sealing the joint. With the smaller of these cylinders the edges overlap or coil slightly, but are so manufactured that they may be forced back and set into a perfect cylinder. In the case of the larger cylinder, the shell is cut into two parts with hinges on one edge, and latches on the other. Bottom and top rings shape the bell and spigot ends of the pipe.

The two cylinders, with joints flush, are set on end, the one centrally inside the other and on the bottom ring, which in turns rests on a firm board bottom. The concrete, made of first-class cement, and clean, screened gravel, is then tamped firmly into the space or mold between the two cylinders. The tamping-iron used to press the concrete into place is so shaped as to fit closely to the cylinder.

The concrete is allowed to stand in the mold for a short time, when the cylinders are removed; the outer and larger cylinder by unfastening the clamps, and swinging the shell open on its hinges; the inner cylinder by removing the fastenings, so as to allow the edges to again overlap, returning to the shape of a coil. The outer cylinder having thus been opened and the inner one made smaller, they can be readily taken away, and the concrete pipe is then left until thoroughly hardened.

The concrete adheres closely to the metal, and to overcome this it is necessary to keep the molds well oiled. This should be done after each tile is made, and when the molds are by this means kept perfectly clean, a smooth and uniform pipe of good appearance will be obtained. A good mixture for oiling the molds is composed of two parts of machine oil to one part of coal oil.

To secure a durable pipe it is necessary to exercise much care in mixing the concrete, and Mr. Campbell particularly advises the use of Portland cement. If gravel is used, it should first of all be clean. Any earthy material, clay, or vegetable mold will create a flaw in the pipe, which will lead to its early destruction, and durability is the quality most to be desired. The gravel should be of a size that will pass through a one-half inch screen, and should be of varying sized grain, in such proportions as to make a compact mixture. The gravel forms the greater part of the mass of concrete, and it is evident that the results will depend very largely on the quality of the gravel.

The materials should be mixed in the proportion of one part of Portland cement to two parts of gravel. They should first be turned over in a dry state until thoroughly intermixed and of uniform color. Water should then be added. This, like the gravel, should be clean, and there should be just enough to moisten the mass of concrete, making it of the consistency of a stiff mortar. An excess of water tends to injure concrete in various ways, and is especially to be avoided in the manufacture of tile, as the tamping cannot be properly performed when too much water is used. When the water has been added, the mixture should be made uniformly moist, by turning it over several times with a shovel. The concrete is then ready to be placed in the molds, in which it should be firmly and vigorously tamped.

Such a quantity of concrete should be mixed as can be put in the molds before the process of setting has commenced, and it is therefore of importance to know how long the brand of cement used can be worked before setting begins. A moderately slow-setting Portland cement is necessary for this work. Ordinarily it is best to mix enough to fill one mold at a time. Remnants of concrete which have commenced to set should be thrown away, in Mr. Campbell's opinion, and under no circumstances should they be worked up again and used, as, he believes, they are certain to cause a defective pipe. Defects which do not appear until after the tile have been placed in a culvert and covered with earth cause not merely the loss of the pipe, but a considerable outlay for labor is wasted as well. The concrete should be handled quickly. Two men are needed, one to shovel it into the molds, and the other to tamp it.

Until the concrete has hardened sufficiently the molds should not be disturbed. When the pipe has attained sufficient strength (which it should do in from five to seven hours, according to the temperature of the atmosphere, and the kind of cement used), it can be taken off the bottom rings. To enable the pipe to set satisfactorily they should be dampened every day for several days, if the weather is dry, and should be protected from the direct rays of the sun in hot weather. They should not be used for some time after being made, but should be allowed to season for from four to six weeks.

The molds for manufacturing these tile may be obtained in various sizes, the more common being for tile ranging from 10 to 30 in. in diameter. The molds are such as will manufacture pipe 2½ ft. long. One set of bottom rings—those for forming the bell of the pipe—go with each set of molds, but it is advisable to have about three sets of bottom rings for each pair of cylinders, to permit the maximum number of pipe to be made in a day.

If the best results are to be obtained from the use of concrete tile culverts, the tile must be put in place with reasonable care, and Mr. Campbell's suggestions on this head read as follows: It is, in the first place, necessary that they shall be laid with a good fall on a regular grade to a free outlet, in such a way that water will not stand in them. Lay the tile with the spigot end down grade, and make the joints tight with cement mortar. If the joints are open, water will work along the outside of the culvert, and finally make a considerable channel, which will allow the culvert to get out of line and finally result in a cave-in. To prevent the water finding its way along the outside of the pipe, it is advisable to protect the ends with concrete, stone or brick head-walls.

Excavate a concave bed for the pipe, with depressions for the bell of the pipe to rest in, thus securing an even bearing, without which a heavy load passing over before the culvert has properly settled into place may burst the tile. Tile cannot be used in very shallow culverts, but must have a sufficient depth of earth over them to protect them from the direct pressure of heavy loads. The depth of covering necessarily increases with the size of the pipe. At least a foot of earth over the top is advisable in every case; but for culverts of 2 ft. in diameter or over, this should be increased to at least 18 in. The earth should be well packed and rammed around the tile to secure a firm bearing, and light soils should not be used immediately over or around the culvert. A heavy clay, a firm gravel, or a compact sand will answer, but vegetable mould, water, sand and light loams are subject to washouts.

As to the outlet, the culvert should be set nearly flush with the surface of the ground. If set higher than the surface, the fall of water will wash out a depression, and in time will undermine the end of the culvert. A too rapid grade will have the same effect, and it is well to cobble-pave an outlet where this undermining action is likely to occur.

The Safety of Crude Petroleum when stored was shown during the conflagration at San Francisco. Storage tanks for oil fuel were placed in many of the business buildings, but according to the local fire marshal none of these tanks caught fire, and some of them are now in use.

Long and Heavy Timber Sheet Piles.

Long and heavy sheet piles were successfully driven for the condensation water conduit of a power house recently constructed by the Scofield Co., of Philadelphia, at Westfield, N. Y. The piles were driven through 12 ft. of water to enclose the concrete walls of a 5x20-ft. conduit 120 ft. long. They were made of 8x16-in. timber 35 ft. long, with splined joints and were driven by a 2400-lb. hammer in leads carried on a 20x20-ft. rolling platform. The rails for the platform track parallel to the conduit were spiked to transverse ties which projected far enough beyond the outer rail to bolt to the upper outside waling piece. An inner waling piece was blocked out from it and rigidly braced. The machine was thus centered on the line of sheet piling and moved forward effectively in position without requiring adjustment or centering and drove the piles with such accuracy that when the tops were sawed off level, the joints between them were scarcely perceptible and no leaks were developed between them.

After the conduit had been completed the pile drivers were dismantled from the platform and the leads were mounted on pairs of transverse cantilever beams overhanging the opposite sides of a scow. This was towed to position in the river in front of the power house and with it the double lines of 12x12-in. sheet piles were driven to form the cofferdam for the intake. The leads had sufficient overhang to drive piles in advance and thus form the track on which they were supported and moved forward beyond the initial position of the scow. After completing the 60 ft. long sides of the cofferdam, the pile drivers were removed from it, set transversely on the scow and drove the end piles, completing the enclosure so tightly that no difficulty was encountered from leakage. The piles had a maximum length of 50 ft. and in order to secure them during driving were connected to the leads with bolts engaging sliding plates. The tendency of these bolts to cramp under the blows of the hammer was overcome by using a special bolt to which a right-angled piece of iron was welded forming a vertical seat on the rear face of the pile. The horizontal portion of the bolt was extended through the leads and a nut on it engaged a vertical bearing plate sliding on the leads with moderate clearness. This device worked perfectly, so that three bolts in each pile held it accurately in position and were successfully removed from the rear as the pile was driven. The work was conducted by Mr. F. H. Hebblewaite, superintendent for the Scofield Co., who devised the details above mentioned.

The Twin Tunnels of the Hudson Co., connecting Jersey City with New York under the North River, were finished about a year ago, and work on the electrification will begin at once. Fifty electric cars will be operated, taking their power from the third rail. The north tube will carry the west-bound traffic, and the south tube the east-bound. The cars will be operated in trains by the Sprague-General Electric system of multiple unit control in a manner similar to that employed on the New York Subway trains. Each car will be equipped with two GE-76, 160-h.-p., railway motors. Power for this new development will be supplied from a large station between Jersey City and Newark. Curtis steam turbines will be employed; initial equipments including two 3,000-kw., 11,000-volt machines and two 6,000-kw., 11,000-volt machines. The total power so generated will be distributed at high voltage to three sub-stations where the alternating current will be stepped down to 650 volts direct current through transformers and rotary converters. The General Electric Co. will furnish the complete electrical equipment.

Progress on the Catskill Mountain Water Supply for New York City.

Plans for providing by gravity an additional supply of not less than 500 million gallons of water daily for New York have now been developed in considerable detail by the Board of Water Supply. The Burr-Hering-Freeman Commission appointed in 1902 investigated all available sources and made exhaustivs reports advising the collection of water by impounding reservoirs in four watersheds of the Catskill Mountains, those of Esopus, Rondout, Schoharie and Catskill creeks. For bringing the supplies thus impounded to New York a system of reservoirs and aqueducts which will ultimately stretch in a 150-mile line from the north side of the Catskill Mountains to Staten Island, will be built. The main Catskill aqueduct will be 85 miles long, extending from the southeasterly corner of the mountains to the highest available site for a distributing reservoir on the northerly boundary of the city. There will be branch aqueducts to the Rondout, Schoharie and Catskill creeks. The completed works will include at least nineteen impounding and distributing reservoirs and will supply water as required to all five boroughs of the city. The Board of Water Supply, appointed in 1905 to build these great works at an estimated cost of about $162,000,000, has made such excellent progress in the final surveys and designs that large contracts for construction will be ready to be let very soon. Esopus creek, having an estimated safe yield of approximately 250 million gallons daily, will be the first source developed. A great dam, to be built at a site known as Olive Bridge, and a few secondary dams or dikes will form the Ashokan reservoir, a few miles northwest of Kingston. This reservoir will be about 12 miles long and have an effective available storage capacity of at least 120 billion gallons. Kensico storage reservoir, with a capacity equivalent to approximately two months' supply at the full flow of the Catskill aqueduct, will be built near White Plains, 30 miles from the City Hall in New York. Just below this reservoir provision will be made for a filtration plant large enough to filter the whole supply.

Esopus Creek from Olive Bridge Site.

In order to make a portion of the additional supply available as soon as possible on account of the impending danger of water famine, it has been determined to hasten the construction of the Ashokan reservoir and the portion of the Catskill aqueduct between it and Croton Lake, so that by means of a special connection to a feeder of Croton Lake about 100 million gallons per day may be added to the present supply and delivered through the two Croton aqueducts in advance of the completion of the new system. Construction of the Catskill aqueduct between Hunter's brook, the feeder just mentioned, and Peekskill creek, a large stream crossing the line about 300 ft. below grade 5 miles farther north, will be particularly pushed, since, as a last resort, a temporary pumping plant could be installed at Peekskill creek in case of emergency to raise water into the aqueduct. It is expected that these works, together with the Croton system, will afford ample supply for 25 years for the needs of the city.

A careful investigation of the subject indicates that the investment in these works will prove a wise and profitable financial transaction. Records of the Croton water system from 1832 to 1898 show that in this period its earnings amounted to $88,017,329.72, while the maintenance and interest charges for the same period were $66,544,245.38, thus showing a net profit of $21,473,084.34. This sum, subtracted from the cost of construction, $86,359,562.09, shows a net cost of $64,886,477.75. The property is still in the possession of the city, is in serviceable condition and is at present under profitable operation. For the first period after its construction, up to 1884, the water-works system showed a loss; from 1875 the records show a profit sufficient to pay the deficiency of the first period, and of late years the profits have been large and increasing, thus showing that the system has a high earning capacity. With this showing for the existing works and with the credit of the city to indorse the new project, the bonds should be a high-class investment.

The Ramapo water scheme, which in former years has been thoroughly discussed in these columns, was a proposition for a private company controlling large watersheds to build works and sell water to the city at the rate of $70 per million gallons. To furnish 200 million gallons daily, as proposed, would have involved an annual payment of $5,110,000 and an expenditure of $15,330,000 per year would be needed on a basis of 600 million gallons a day, the quantity to be supplied from the Catskill plant. But the Catskill system involves an interest charge at 4 per cent. of only $6,440,000 a year, plus a sinking fund charge for long-term bonds, and at the same time secures the ownership and control of the system to the city all the time.

All surveying, designing and supervising of construction for the new water works is done by the Engineering Bureau, which has been organized since Aug. 1, 1905, and is one of the largest municipal engineering staffs. It now includes a total of about 460 engineers, assistants, clerical employees and laborers and reaches a maximum of 550 during the summer. This force has been organized under municipal civil service regulations, which has considerably increased the difficulty in securing men of the necessary ability and experience as rapidly as needed. The Engineering Bureau now comprises four departments. The Headquarters Department in New York has charge of the executive work relating to the Engineering Bureau as a whole, civil service matters, the selection of employees, designs, specifications, contracts, experimental investigations, tests of materials and purchase of equipment and supplies. The Reservoir Department, with its office in the Catskill Mountains, at Brown's Station, has in hand the surveys and construction of the reservoirs within the watersheds. The Northern Aqueduct Department, with main offices at Poughkeepsie and numerous small offices along the line, has charge of 58 miles of the 500-million-gallon aqueduct between the Ashokan reservoir and the Croton watershed. The Southern Aqueduct Department, with main offices at White Plains and several small offices elsewhere, has charge of the remaining 27 miles of aqueduct, the Kensico storage reservoir and the terminal distributing reservoir at Hill View, at the city limits. Another department, in charge of the development of the ground-water supply in the east part of Long Island, is just being organized, and a department to construct the filteration plant near White Plains will be organized when wanted.

It is the policy of the Engineering Bureau to make the preliminary estimates, comparisons and investigations so thoroughly that all essential information shall be secured and preparation be complete before construction is undertaken or the final plans adopted. This policy is justified by the large saving in the ultimate cost of the system by avoiding mistakes and delays and by the greater efficiency of the work for which such preparation has been made. Several large maps, with estimates and reports, were made for the State Water Supply Commission soon after the Board was organized and while its engineering staff was very small. This work was estimated to take one year and to cost $100,000, but was accomplished in four months at a cost of $43,000. The project then presented was approved in most of its features on May 4, 1906, after seven public hearings which involved extensive special reports and elaborate engineering investigations. Simultaneously with this work there was carried on other preliminary work in anticipation of a favorable decision by the State Commission, so as to make the utmost saving of valuable time and secure the delivery of a portion of the additional water supply at the earliest possible moment, in order to relieve the anxiety felt concerning a water famine, which for some time has been acknowledged imminent whenever a prolonged drought shall occur.

Physical, chemical and photographic laboratories have been established in a suitable building in New York. Among the preliminary investigations in progress is an extensive series of experiments undertaken to decide to what extent large reinforced-concrete pipes can be used under pressure. Investigations are being made for the filtration of the water supply. Rain gauges have been established in the watersheds, and all available data of rainfall and stream flow have been collected, digested and applied in determining the economical sizes of the reservoirs. Several dam sites have been explored and studies for the different types of large dams are in progress. Numerous samples of soil have been collected from the principal reservoir sites to determine the treatment of the reservoir bottoms, and many samples of sand, gravel and stone have been secured along the line of work and sent to the laboratory to be tested for availability for construction. Samples of many commercial structural materials have also been secured and are being tested.

Systems have been developed for filing and indexing letters, reports, records, drawings, computations, books and photographs, as outlined in this journal on Sept. 29. Numerous standards are being, and have been, developed for the details of regular operations. A book of instructions for the guidance of the members of the Bureau has been printed and issued. The architectural department of the Bureau has designed buildings for the accommodation of the field forces, and portable houses of special design have been constructed for parties in regions where it was not feasible to quarter them in existing structures.

A summary of the financial statement dated Sept. 1, 1906, shows the total expenditures of the Board of Water Supply from June 9, 1905, to Aug. 31, 1906, the principal items of which are as follows: Expenditures by Administration Bureau, $90,404.24; expenditures of Engineering Bureau, $501,281.74; liabilities, $174,520.77, thus giving a total of $766,206.75, which subtracted from the $1,602,000 of corporate stock authorized to date, gives a balance of $835,793.25 now available.

So much preliminary work has been completed that several important locations have been determined and final designs are in progress. It is expected that contracts will be awarded during this fall and winter for the construction of the great dam for the Ashokan reservoir and for several large sections of the Catskill aqueduct between the reservoir and Croton Lake, including the difficult crossing under the Hudson River. It is interesting to compare the progress indicated by this condition of the work with that in some other municipal undertakings. For the recently completed Metropolitan water works of Boston, the engineering department, with the advantage of an excellent preliminary study by the State Board of Health, devoted eight months to organizing, surveying and designing before the first contract was let for the Wachusett aqueduct and a considerable longer time for the Weston aqueduct. For the preliminary work for the Croton aqueduct of New York more than eighteen months were required. On account of the difficulty of the construction and various important considerations involved, nearly six years elapsed after the New York Board of Rapid Transit Railroad Commissioners was created before it commenced construction. The Philadelphia filtration system required one and one-half years' preliminary work, and the Boston subway eight and one-half months' preliminary work before construction was commenced. It is thus seen that abundant precedent exists in municipal works, even of less magnitude, for devoting considerable time and expenditure to investigations and preparatory work before construction is commenced and that these items have not been exceptional in the case of the new water supply for New York.

Ashokan reservoir on Esopus creek will be the largest in the system and will be the largest for high-pressure water supply in the world. The main dam will probably be built partly of masonry and partly of earth. The water impounded will inundate eleven villages and form a lake over 11 miles long and 1⅓ miles wide, with an area of 8,000 acres, a shore line of 50 miles, and a maximum depth of 180 ft. To prevent pollution, about 4,000 acres of adjacent land must be brought under control and nearly 700 buildings will be removed. Twelve and one-half miles of railroad track and 60 miles of highway will be relocated. A secondary earth dam, 2½ miles long at Brown's Station and 1½ miles of dikes at West Hurley will also be built for this reservoir.

In order to locate the flow lines and property boundaries and determine the capacities of the Ashokan reservoir and the Kensico and Hill View reservoirs near New York, nearly 17,000 acres of land have been surveyed and accurate topographical and property maps have been made. Some of the property surveys have been done at the rate of 500 to 600 acres a week and at an average cost of $1.32 per acre, and some of this mapping has been done for $1.10 per acre.

Two sites for the main dam of the Ashokan reservoir have been considered. Approximately 15,000 lin. ft. of wash and diamond drill borings and several deep shafts and trenches have been sunk to explore them. Studies by geologists and comparative estimates of cost based on the information thus gained have resulted in the selection of the Olive Bridge site, nearly a quarter of a mile below Bishop Falls.

It is intended to construct most of the aqueduct on the hillsides, following the tours with a slope of a little more than 1 ft. per mile. Where deep valleys are intersected they are to be crossed with inverted syphons consisting of deep tunnels driven wholly in solid rock, in some places far below the surface, and shafts connecting with the adjacent portions of the aqueduct at grade. These syphons will be lined with concrete and made strong enough to withstand the enormous pressure of the water. The tunnels of the Hudson River crossing may be as much as 500 ft. below the surface of the river, and hence 900 ft. below the hydraulic grade line. Valleys not exceeding 100 to 150 ft. below the hydraulic grade line will probably be crossed by pairs of reinforced-concrete pipes about 12 ft. in diameter or several large steel pipes, depending largely on the results of the extensive experiments with reinforced-concrete pipes now in progress. In order to secure the best location of the aqueduct, preliminary lines were surveyed covering strips in each case about 1,000 ft. wide and aggregating nearly 250 miles in length. About 5,000 lin. ft. of borings have been made to explore the rock, especially at the syphon sites, besides many rod soundings along the cut-and-cover location. Borings and soundings are still in progress.

In many places the geological structure of the country is such as to make the underground investigations exceedingly difficult. Great numbers of boulders in the overburden of earth make the results of wash borings very uncertain, and penetrating them with any means available in order to reach bedrock is slow and expensive. The great depth of water, the tidal movement, and the large traffic in the Hudson river have rendered the examination of proposed crossings tedious and costly. Many lines for this crossing and its connections have been explored, extending over 20 miles of the river, from West Point to a point about 4 miles south of Poughkeepsie. Most of these surveys have been made within six months, although it was considered that two years would be a reasonable time for doing such an amount of field work.

Bishops Falls Above Ashokan Dam Site, 100 ft. Below High-Water Level.

The subterranean explorations have been made with various types of boring machines, and have been executed both by the Engineering Bureau and by contractors. Some shot drills have been used. Diamond drill cores have been made from 1 to 1¼ in. in diameter and to a maximum depth of about 500 ft. Five diamond drills are now in the field, most of them made by the Sullivan Machinery Co., and operated by portable boilers. In some cases the drilling machine is mounted on a wagon and also carries the boiler. Sectional wooden houses have been built in some cases to shelter the boilers and machines. Wash borings were made in the usual way with double pipes driven by hydraulic jets and hand hammers; the details of the apparatus having been adapted from those ordinarily used for such purposes. There are twelve wash drilling parties, each of them consisting of four men besides a recorder, who in some cases takes notes for two or more drilling parties.

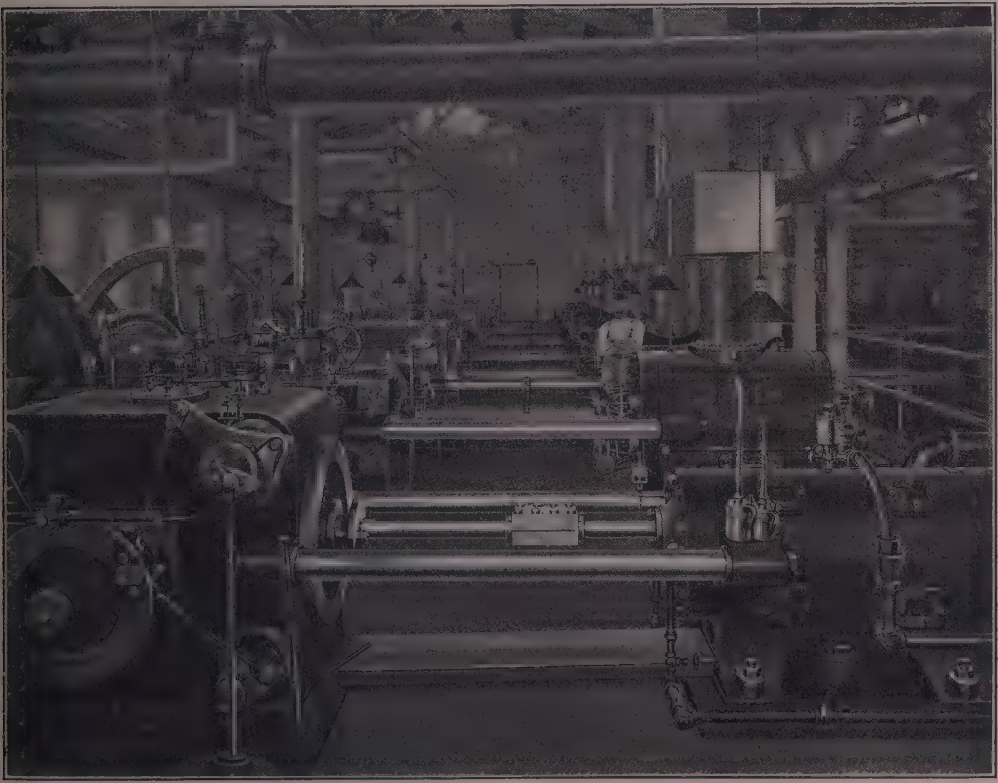
The records of the drilling parties are kept on daily report sheets and filed in the department offices. The blank for diamond drill reports gives the foreman's name and has vertical columns for the identification number for the hole, the previous number of feet and the number of feet drilled each day. The column footings show the total depth of each test hole and at the foot of the page spaces are reserved for statement of the number of single and double teams used and laborers, etc. The blanks for the wash borings give name of the line, serial number for each hole, the number of feet previously driven and number of feet driven on the current day and the total depth. They also show at the foot of the page an estimate of cost and record of time for the foreman, laborers, teams and extra teams, the rate per day, the total cost and the amount of pipe used.

Both of these blanks are filled out daily and submitted to the resident engineer. From them he prepares a summary for the department engineer on small blanks, each of which bears the date, the location, the serial numbers of the holes, the depths drilled on the current day, the total depths drilled and the materials encountered.

Exploration at the principal dam sites have also been made by sinking 16x24-ft. shafts to the depth of 85 ft. These shafts were excavated by pick and shovel and sometimes a small amount of blasting. The material was hoisted in one-yard steel buckets by steam derricks and was deposited in spoil banks at the tops of the shafts. The shafts were heavily timbered, and in some cases the buckets were emptied into dump cars on light trestles built out to extend the spoil banks a considerable distance from the shaft, thus displaying the character of the material passed through in a continuous pile corresponding to the different strata and showing them in their proper sequences. In other cases the hillside at the proposed dam site has been explored by trenches about 4 ft. wide, 6 to 12 ft. deep, stepped up the slopes. The lower parts of these trenches were carried down to rock when it was not too deep, and above it the bottoms of the trenches were stepped with vertical offsets to display the character of the soil, so that the engineers and contractors could determine its slope of stability, its weathering qualities, its availability for construction purposes and other qualities.

In order to determine accurately the flow of the Esopus creek a concrete measuring weir is now being constructed below the Olive Bridge dam site. Its cross-section is one of the types included in the Cornell University experiments of 1903, and described in Water Supply and Irrigation Paper No. 150 of the United States Geological Survey. It is 210 ft. long on the crest, with foundations on the solid, nearly horizontal rock forming the bed of the creek, to which it is anchored by vertical twisted steel rods. Concrete is mixed by hand on the shore and delivered to the forms as required. At low stages of the creek the water varies from a few inches to about 2 ft. in depth, and is diverted from successive sections of the foundations by sand-bag coffer dams.

The Board of Water Supply consists of Messrs. J. Edward Simmons, Charles N. Chadwick and Charles A. Shaw. Mr. J. Waldo Smith is the chief engineer. Mr. Alfred D. Flinn is engineer of the Headquarters Department, Mr. Carleton E. Davis engineer of the Reservoir Department, Mr. Robert Ridgway engineer of the Northern Aqueduct Department, and Mr. Merritt H. Smith engineer of the Southern Aqueduct Department. The consulting engineers are Messrs. John R. Freeman, Frederic P. Stearns and William H. Burr. Messrs. Allen Hazen and George W. Fuller have been retained to advise on the matter of stripping soil from the reservoir bottoms and the filtration of the water. Prof. J. F. Kemp, of Columbia University, and Prof. W. O. Crosby, of the Massachusetts Institute of Technology, have been retained to make a study of the geological problems.



Air Compressor Plant for the North River Tunnels.

The Rating of Internal Combustion Motors in Germany has been the subject of an investigation by the imperial treasury department, and as a result the motors for automobiles are to be rated by the formula, $N = 0.3\ id^2s$, in which N is the horse-power, i is the number of cylinders, d is the diameter of cylinder and s the stroke, the quantities being in metric measures. The formula is based on 900 r.p.m. and a mean pressure of 3.8 kg. per square centimeter. This formula has also been adopted by the Automobile Association of Central Europe.

Air Compressing Plants for the North River Tunnels of the Pennsylvania R. R.

By Frank Richards.

The recent meeting of the ends of the first tunnel of the Pennsylvania R. R. under the North River, connecting Manhattan, New York City, and New Jersey, and the fact that a similar junction of the ends of the second tunnel will probably be effected before the publication of this article, call special attention to the power plants of the O'Rourke Engineering Construction Co. on each side of the river by whose reliable and constant operation the work has been carried so smoothly and so rapidly —as such things go—to such successful completion. The two plants are precise duplicates of each other as to the several members installed, but the arrangement of the units is different in each according to the opportunities of the location. The temporary character of the installations is sufficiently indicated in the buildings and surroundings, the Manhattan plant being located in an old shop which has only been changed sufficiently to give convenience of operation, and the plant on the New Jersey shore is housed over with sufficient cost and care to give perfect and secure shelter and bettter accessibility than the other plant.

There is nothing whatever which can be pointed out as of a temporary character in the mechanical installations. It was recognized at the beginning that the period of employment of these plants was to be sufficiently long to make the cost of daily operation an important consideration, and the plants accordingly embody in design and operation the chief essentials of high steam and fuel economy in the generation of the power employed, and a corresponding economy and efficiency in the application of the power to the specific work required. Indeed it may be said that in comparison with the cost of operation of too many air compressing plants employed upon mine and tunnel and excavation work the machines here employed, with all their adjuncts and appurtenances, will undoubtedly pay for themselves more than once in their saving of fuel cost before their work in the neighborhood is finished, and after that they will still be ready for other employment as exacting and for work as reliable and effective in connection with other great engineering undertakings. This high economy of operation is not the characteristic of the present plant alone, but is common to most of the recent installations for tunnel work and work associated with the tunnel enterprises in and around New York City. There are about 100 air compressors in all now employed upon the railroad transit undertakings of New York, while the two O'Rourke installations here considered include less than one-eighth of the whole either in numbers or in aggregate capacity.

All the familiar conditions—not, however, carried to extreme attenuation—of high economy in the general employment of steam are embodied in the machinery and appurtenances here installed. The steam is supplied at comparatively high pressure, the steam cylinders are compounded, with cut-offs adapted to the equitable distribution of the steam for the development of the required power and a good vacuum is carried. The air intake delivers the coolest air within reach, the air cylinders are completely water jacketed, and after-coolers complete the cooling and drying of the air and guarantee its delivery in the most satisfactory condition for use.

For this tunnel work the air was required to be maintained at two quite different pressures, the high pressure and the low-pressure air being supplied by different compressors and requiring separate piping throughout. The low-pressure air, which was required in much the greater volume, was used to overcome the pressure of the water and prevent the inrush of the silt as the removal of the material in front of the shield proceeded. The air thus supplied, it is to be remembered, constituted the entire atmosphere of the men working in the tunnel advance, so that both its temperature and its purity or freedom from oily vapor or other objectionable smells was essential. In this respect the air has been as satisfactory as in any similar use of it, which seems to be all that is possible, and the volume delivered has been usually ten times as great as theoretically required for normal respiration. The pressure of the low-pressure service has not exceeded 30 lb. gage, and usually has not been above 25 lb.

The high-pressure air being required for operating rock drills, pumps and hoists and other equipment, and the exhaust from these being into the "low" pressure compressed air or at a pressure nearly two atmospheres higher than normal, the working pressure was also required to be maintained with this excess of pressure above the 6 or 7 atmospheres usually carried for such work. The high limit demanded for the low-pressure service was 50 lb. gage, which pressure was never actually carried or called for; the limit similarly for the high-pressure air was 140 lb. gage, which also was greater than required under the actual conditions encountered.

For the low-pressure service in each of the plants there are three similar Ingersoll Corliss compressors with cross-compound steam cylinders and duplex air cylinders, the dimensions being: Steam cylinders, 14 and 30 in. diameter by 36 in. stroke, and air cylinders, both 23¼ in. diameter, the normal aggregate free air capacity at 500 ft. per minute piston speed being 8,655 cu. ft. per minute.

These compressors have all the usual features of machines of this type. The air valves, both inlet and discharge, are themselves thrown in either direction by air-operated mechanism, so their openings and closings are both rapid and precise. The Corliss steam valve gear in connection with the automatic pressure governing devices accurately regulates the speed of the compressors according to the air consumption. The perfection of this governing action and the immediate and constant responses of the machines to the slight fluctuation of air pressure up or down are excellent. While the compressors will work down to extremely slow speeds and still keep in motion they can be trusted never to run away, even if all the air pressure disappeared, the high speed being then held in control by the fly ball governor.

The fourth machine, the high pressure compressor, is also a Corliss compressor with cross-compound steam cylinders and duplex air cylinders, the former being 14 and 22 in. diameter by 36 in. stroke, and the lattetr 14¼ in. diameter. In these air cylinders the piston inlet is used instead of the mechanically operated valves, the special features of the piston inlet applying very neatly in this case. The compressing of free air to 140 lb. by single stage compression is, of course, not normally good practice. This compressor, which has a free air capacity of 1,070 cu. ft. per minute is also designed to take in the low pressure air from the compressors of the first series, which being at, say, 30 lb., or three atmospheres, increases the capacity of the compressor threefold, and this compressor then becomes the second member of a two-stage compression. When worked in this way, as in fact it usually has been, the compressor is doing its work of air compression with excellent economy, and if worked up to speed it would deliver the equivalent of over 3,000 cu. ft. of free air per minute. When working, as it usually does, under a constantly varying load the speed constantly changes, and the varying demand for air to supply it also necessitates changes of speed in the low-pressure compressors, but these fluctuating demands, thus affecting both the high and the low-pressure service at once, are entirely and perfectly taken care of by the automatic speed and pressure regulating devices.

This compressor may be used in three ways: First, in compressing free air to the low-service pressure, and so far helping out if the supply of low-pressure air should be deficient; second, compressing free air directly to the high pressure—that is, 140 lb. maximum; third, recompressing the low-pressure air to the high pressure. The piston inlet pipes of this compressor extend out through bracket-supported stuffing boxes and from these stuffing boxes pipes and suitable valves connect with the after-coolers of the low-pressure cylinders, or the same pipes conduct free air to the compressor. When taking the air from the low-pressure compressors their after-coolers perform all the functions of the usual intercoolers.

It will be noticed that the proportions of the steam cylinders of this fourth compressor are quite different from those of the three low-pressure compressors, although using the same high-pressure steam. The fact, in explanation, is that the steam engine portion of the machine, and also that of the similar one in the plant across the river, is not new and was designed for the lower steam pressures in use a few years ago. These engines being in existence and in good condition Ingersoll-Rand air cylinders were built on them, and they make quite excellent compressors, although not theoretically perfect in the one detail of cylinder proportions when such high steam pressure is used.

Besides the air compressors there are installed in each power house two General Electric continuous-current generators direct connected to Ball-Wood engines. There are also three duplex hydraulic pumps for the jacks which advance the shields in the tunnel headings. These maintain a constant water pressure of 4,000 lb. A small machine shop with a few necessary tools, driven by an independent vertical engine, is included. Two Worthington surface condensers each of sufficient capacity to take care of the entire exhaust, maintain a constant vacuum of 26 in. Circulating pumps provide a constant flow of river water through all the water jackets.

The boiler plant of each power house comprises three Stirling water-tube boilers of 500 h.-p. each, two being always sufficient, and the third serving as a reserve. Each boiler has four furnaces, hand fired, using buckwheat anthracite coal. The water supply is kept up from the city mains, duplicate duplex feed pumps delivering it. A Cochrane feed-water heater makes use of the exhaust from the hydraulic pumps and various auxiliaries. An air-driven hoisting engine takes the ashes to the street level, the coal coming down by gravity.

The piping of the plant throughout, for steam, water or air, high or low pressure, provides for throwing out or connecting each unit independently of all the rest, and is intended to cover, as it has actually, every contingency of constant service or of possible accident.

These tunnels are as yet the largest subaqueous tunnels in the world. Work upon them was started by the O'Rourke Engineering Construction Co. on April 13, 1904, and the contractors have a unique record in engineering in having brought the shields to meet twelve months ahead of the contract time. The record of the air compressing plant is quite comparable with that of the work as a whole, and it also can only be characterized as unique. No change or addition has been required for the plant from the beginning, there has been no stoppage or delay for breakdowns or repairs and its capacity, notwithstanding the crowding of the work, has always been sufficient for every demand.

With the completion of the shells of the tunnels the work is still far from finished, and the most uncertain and tedious and perhaps most difficult part of the work remains. The tunnels were begun in solid rock on each side of the river, a large number of Ingersoll-Rand rock drills having been employed upon this part of the work. Soon after leaving the river bank on both sides the rock disappeared and thereafter all across the river the tunnels were pushed through silt so soft and yielding as to afford no safe support for the tunnel tubes, and their stability and permanence can only be assured and the weight of the trains to be run through them can only be safely supported by some construction under the tunnel tubes. Such a construction is in fact to be built, all the work being done from inside the tunnel tubes. The compressed air, probably at a somewhat higher pressure, will be required all through the job, to withstand the inward pressure of the fluid or semi-fluid material surrounding the shells.

In the bottom of the tunnel casings at intervals of 15 ft. holes with removable covers have been provided, and through these holes screw-piles are to be driven down either to solid rock or to material of sufficient stability. It is understood that it will be necessary to sink many of these piles to a depth exceeding 150 ft. The piles will be made in lengths of 10 ft. and accurately machined on the ends, and these will be successively and securely bolted together one after another until the required depth is reached or a proper stability is assured. Arrangements will be made to stop or finish the piles so that the tops of them will be connected by strings of I-beams which, properly bound together, will constitute the deck or horizontal member of a bridge, and this will support all the weights to be carried, while the tunnels will exclude the liquid and will secure against everything subaqueous the right of way. The success of the enterprise thus far guarantees its rapid continuance to completion.

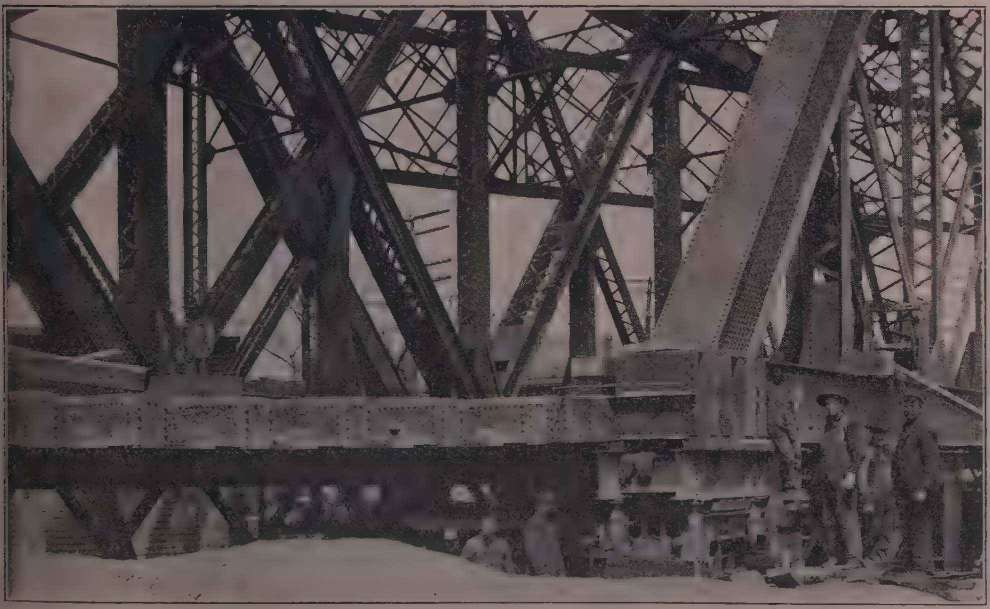
RUN-OF-CRUSHER STONE will be used for concrete on the Roosevelt dam, and the additional stone will be supplied by a crushing plant capable of producing in 8 hours about 60 yd. of sand, crushed from limestone so as to all pass a ¼-in. mesh screen. The dam will contain about 350,000 cu. yd. of masonry, and all the sand necessary will be supplied from this plant, except for the concrete, where only such additional amount of sand will be added to the run-of-crusher from the contractor's crushing plant as is necessary to make up the required amount. This is estimated to be 10 to 15 per cent., but it may be more or less. The dam will be built of sandstone, and a limestone or a dolomite limestone is used for the sand. Tests so far made on this sand give a tensile strength of approximately twice that with standard sand, using the same proportions of cement. This peculiar strength of concrete made with limestone sand has been shown by work elsewhere. For instance, Messrs. Ruggles & Lucas, of Nevada, Mo., formerly made the top dressing of their sidewalks from a 2:2 mixture. Recently they began using sand obtained by crushing Carthage, Mo., limestone, and find they can make a harder, smoother and more nearly white surface with a mixture of 1 part cement to 2 parts of limestone sand. Limestone screenings are also being used instead of sand, with excellent results, in the construction of the immense retaining walls along the head race of the water power development of the Chicago Drainage Canal. The concrete is made 1 part cement, 2 parts screenings and 5 parts broken stone. Run of crusher screenings with a maximum size of ¼-in. and ¼ to 1-in. stone are used.

Elevation of a Four-Track Railroad Bridge.

Improvements are now being made on the line of the Mohawk Division of the New York Central & Hudson River R. R., at Schenectady, N. Y., including the abolition of grade crossings and the consequent elevation of tracks within the city limits. Among the difficult problems developed by this work was that of repairing and raising a four-track span 162½ ft. long center to center end bearings, which crosses the Erie Canal at Union St. This bridge has three riveted through trusses and a ballasted floor carried on solid riveted troughs of the standard pattern. The total weight of bridge and ballast is estimated at 1,350 tons. The trusses make a very acute angle with the axis of the canal, and as the floor troughs are perpendicular to them, one end of a number of sections at each abutment is supported on the masonry.

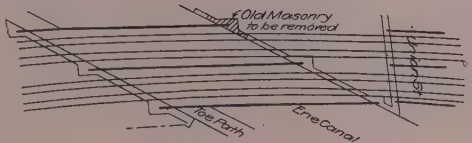
It was necessary to raise the old masonry to suit the new grade and to rebuild one end of one abutment. The east abutment was integral with a cross wall transverse to the bridge axis thus enclosing two sides of a large triangular space adjacent to the span across which the tracks were carried on trestle work. All of these conditions, together with the large number of trains crossing the bridge at all hours of the day and night, increased the difficulties of the work and the methods by which it was finally accomplished, are of special interest on account of their simplicity and the success attending their use.

The tracks are numbered consecutively one, two, three and four, commencing at the south side of the bridge. At the beginning of operation, tracks three and four were abandoned and the east end of the north truss, adjacent to track four, was supported at panel points, L2, L3, L4, on the caps of falsework bents, each having two vertical piles driven from below the bridge clear of the truss on each side. The stiff bottom chord was wedged securely on the caps and thus carried the structure independently of the end bearings which were released. The north end of the abutment was removed and rebuilt and repairs and extensions were made to the rest of the sub-structure masonry. After their completion the truss was re-seated on the masonry and the ends of the floor troughs were also blocked up on the abutment and the excavation around the latter was back-filled.


View Showing Jacks in Place.

Traffic having been resumed on tracks three and four, it was abandoned on tracks one and two, and the falsework trestle was constructed beyond the abutments with the caps at a higher elevation to carry the tracks at the new grade. The Union St. abutment transverse to the bridge axis and intersecting the south end of the old east abutment was also built at this time in readiness for a future modification of the super-structure. Pony bents of framed timber were set on the solid floor of the bridge to carry tracks one and two at the new elevation and the rails were laid on them continuous with those on the approach falsework. The plan called for portals and sway-bracing over tracks one and two to be removed, leaving the top chords connected only by the lateral struts and diagonals. This was avoided by building the cribbing 1½ ft. lower than called for on plan and lowering the grade on the approach. Excavation was made behind the abutments under tracks one and two, and the masonry changes were completed there as nearly as possible. Traffic was then resumed on tracks one and two and again abandoned on tracks three and four, and the bridge was raised about 7 ft. to final grade.

Span While Being Raised.



Arrangement of Trusses and Abutments.

In order to support the oblique ends of the floor troughs formerly resting on the abutments, old lattice girders were swung underneath the bridge floor at each end parallel and as close as possible to the abutment walls. They were braced against buckling and were secured by yokes and vertical suspension bolts from the bottom chords, thus temporarily carrying the ends of the floor troughs. A pair of 24-in., 100-lb. I-beams 10 ft. long parallel to the bridge axis were set as close as possible to each lower chord at the end with their top flanges about 3 in. clear of the lower flanges of the bottom chord. The beams were about 3 ft. apart on centers just clearing the webs of the pedestals which supported the truss. Each pair of beams was fastened together at both ends by a pair of horizontal 15-in. I-beams web-connected to them with field bolted vertical angles, thus forming a rectangular framework enclosing the pedestals and suspended from the superstructure by vertical bolts with hooks at the upper ends engaging the sides of the floor troughs. The spaces between the top flanges of raising beams and the horizontal legs of lower flange angles of bottom chords were filled with oak blocks reinforced against splitting with ⅝-in. bolts. Outside the chord angle legs fillers were placed to bear on lower flanges of the floor troughs. Heavy oak blocks forming solid brackets were placed in the troughs with their upper ends bearing against the top flanges of the chords and their horizontal lower edges about 3 in. clear of the lower flanges. Pairs of folding oak wedges were inserted in this clearance and being driven up, provided solid bearing between the chord flanges, filler blocks, brackets and tops of the I-beams, thus developing the strength of both flanges of the bottom chords. Four 100-ton jacks were then set under the I-beams at each end of each truss, making 24 jacks in all. At one end of the center truss one of the jacks took bearing against the bottom flanges of both transverse beams, being placed in this position on account of the clearance required by the skew of the bridge. In all other cases all of the jacks took bearing directly on the lower flanges of the longitudinal beams.

The jacks were at first seated on the top of the masonry and were operated to raise one end of the bridge at a time for a lift of 6 to 8 in. The time required for this lift was about 12 minutes. At the same time, both tracks were dropped for their whole length for the whole 8 in., and if the raise was not made on both ends by the time a passenger train was due, a run-off was made on the bridge. The run-offs were made very quickly; five minutes sufficing to make them.

As the jacking progressed, the blocking was changed piece by piece so that it was never entirely removed and the wedges, tapered 1:12 and made the full length of the shoe, were kept constantly driven tight so that no appreciable clearance remained between them and the steel work. As fast as the bridge was raised to the full stroke of the jacks, the latter were released. In order to facilitate releasing of jacks, after each lift a steel plate was put on the blocking and steel wedges, 5 ft. long under center truss and 3 ft. long under side truss and a batter of 1½ in. in the length of wedge, were driven tight with a 16-lb. hammer, thus taking considerable load off the jacks and preventing possible breakdown of the latter due to releasing unequally. Supports were provided for the jacks by steel cribbing built up on the masonry to the ultimate height shown in the elevation. This cribbing consisted of sets of 15-in. I-beams bolted together and arranged as shown in the accompanying illustrations in such a manner as to afford three independent supports, one for each pair of jacks and one for the shoe. While the jacking was in progress the different sections of steel cribbing were bolted together as indicated by the drawing. As the jacking progressed, transverse 8x8-in. cap timbers in the pony bents on the solid floor were replaced by sets of 2x12-in. plank, 3 ft. long, which were successively removed to compensate and maintain the track level as the bridge rose. Whenever it was necessary for trains to cross the bridge, special care was taken to block firmly under the shoes and the ends of the unsupported troughs.

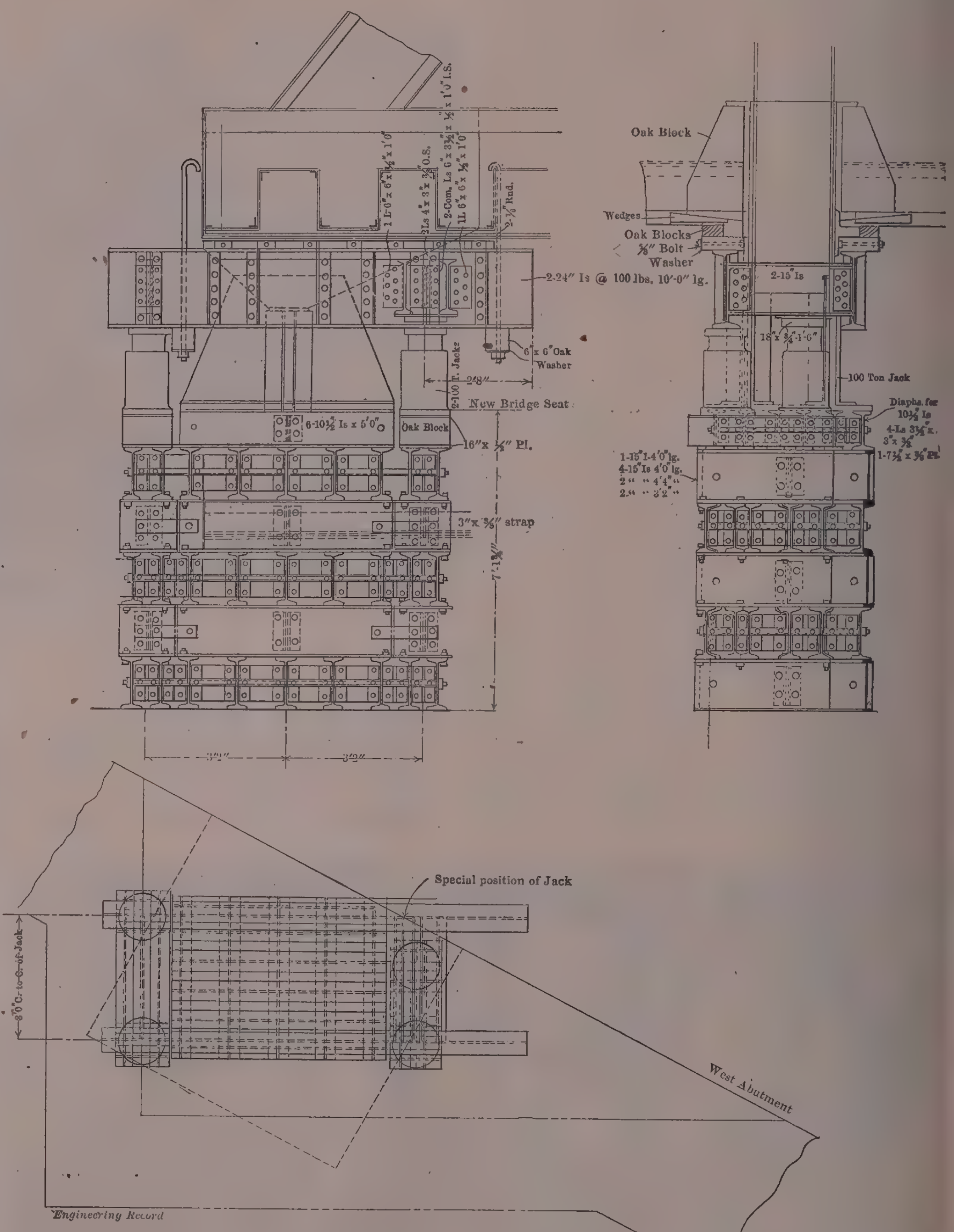
In raising, no stop was made for concreting in the grillages. A three-mile order was placed on the bridge and the sway of the steel as the grillage pedestals kept getting higher, was not sufficient to warrant stopping the work to concrete in the grillages. When the raising was complete, angle braces were put in, running from the tops of grillages to the old coping on about 45° slope, and being anchored to the masonry, and bolted to the grillages, helped to brace the bridge considerably.

It took about five minutes to put in a grillage under one of the jacking points, after a sufficient lift had been made. Gin poles were erected at each end of the center truss, to handle the grillages for the two center points. The grillages under the outside corners were handled by hand.

The work was started after train No. 10 on Monday, April 23, and the iron was up in place by noon on Wednesday, with the exception of putting in the roller nests, which work was done by 2 p. m., on Wednesday. On Wednesday afternoon, the Union St. trestle and also the trestle at the west approach of the bridge were raised to conform with the new grade. The work was done between passenger trains, and none were held up, with the exception of No. 64 for twenty minutes on Wednesday, and running No. 63 around on track No. 1 on Tuesday and Wednesday. No raising was done after train No. 62, at 3:50 p. m., on either of the three days. There were altogether on this job about ninety-five men, of whom sixty men were at the jacking points, and thirty-five were on the deck to take care of the tracks. There were ten men at each jacking point, eight of whom were at the jacks, and two shifting blocking.

After raising was completed, the jacks and girders were removed, the span being left supported on the grillages. The walls were then carried up with concrete around the grillages, all of the openings in which were completely filled with concrete.

The work was planned under the direction of Mr. W. J. Wilgus, vice-president; Mr. C. J. Parker, principal assistant engineer, and Mr. A. W. Carpenter, engineer of bridges. The work was executed by the railroad company's forces, under the direction of Mr. G. W. Vaughan, engineer of maintenance of way; Mr. C. E. Lindsay, division engineer, and Mr. N. W. MacCallum, supervisor of bridges.



Plan and Details of Steel Blocking used in Raising New York Central R. R. Bridge at Schenectady.

A Suit Against a Water Company for losses due to a fire, where the water supply was defective, was recently brought before the Alabama Supreme Court, 41 South. Rep. 76. The court followed the precedents of the courts of most other States where the question has arisen and decided that a resident of a city cannot recover damages for loss by fire, occasioned by the failure of a water-works company to furnish a supply of water in accordance with its contract with the city.

A Large Counterbalanced Dredge.

A floating dredge that has been used very satisfactorily on smaller work has recently been designed for a large capacity in heavy work and presents some special features of arrangement and operation. It has a hull about 135 ft. long and 45 ft. wide, with a boom 66 ft. long on centers which carries a Hayward clam shell bucket of 10 cu. yd. capacity. As the weight of this bucket empty is about 16 tons in air, and its weight when filled with wet mud is about 31 tons in air, and only 22 tons in water, the difference of 9 tons causes a great irregularity in the stresses developed by hoisting in and out of the water. To equalize these stresses and to make the service of the hoisting machinery more uniform, the bucket is provided with an adjustable variable counterweight arranged to take up about 11 tons of its weight when it rises above water line and to throw nearly the full weight on the hoisting engine when the bucket is below the surface, so that it will sink rapidly. This compensating arrangement permits a more uniform operation of the engines and tends to promote economy of work and maintenance.

The boom has a horizontal radius of 53 ft., which gives it a reach of 22 ft. in advance of the dredge and 30 ft. on each side, thus enabling it to command a considerable area in one position of the dredge. The heel of the boom is pivoted to a turn table 21 ft. in diameter, on which is seated the single drum, double cable, main hoisting engine in the same vertical plane as the boom, thus providing a direct line for the hoisting rope and effecting an estimated economy of 30 per cent. in power and wear. The point of the boom is supported in a fixed vertical position by steel rods pin-connected to it and to a swivel at the top of the shear legs 52 ft. high. The feet of these legs clear the turntable and have fixed pivots on the anchor spud frame, about 5 ft. above the deck. The top of the shear legs is inclined slightly forward and is attached to a longitudinal strut about 60 ft. long on the center line of the dredge. The opposite end of this strut is supported on a vertical column 34 ft. high and is anchored by a forked back stay reaching to the stern of the dredge and clearing the stern spud.

The longitudinal strut serves as a track for counter-weights attached to a steel cable passing between horizontal guide sheaves at the shear legs and thence over a sheave at the end of the boom and down to the bucket which is supported by it and by another line led over a second sheave at the point of the boom and directly back to the main hoisting engine. The proportion of the counter-weights and the arrangement of the lines is such that when the bucket is in the water, the counter-weight is supported by the inclined strut on a track graded sufficiently to insure positive motion in the counter-weight without putting much tension on its rope. When the top of the bucket rises to the surface of the water, the counter-weight reaches the lower end of the inclined strut, and as the bucket continues to rise, it abruptly descends vertically, throwing its full effective weight on the hoisting line and relieving the engine until the bucket descends below water level and the counter-weight runs away from the vertical to the inclined track and its tension on the hoisting rope is only sufficient to take up the slack of the cable. The counter-weight track is extended aft from the foot of its vertical hoist, where it can remain in equilibrium at the bottom of the dredge if necessary for inspection or adjustment. By this arrangement and the location of the hoisting engine on the turntable the counter-balance is always effective and the bucket can be operated at full radius on either side of the dredge without causing excessive list.

The dredge is anchored in the usual manner by two vertical spuds forward and one aft. The turntable is operated by a single engine, conveniently located just forward of the counter-weight guides, which drives a transverse shaft operating the drums. The same shaft is also provided with a clutch for the operation of the two vertical spuds, and another drum connected to the counter-weight. A third engine aft operates one spud, anchor chain, and winch heads, all on the same shaft. The six deck capstans are operated by one engine on each side of the dredge, below the deck. All main operations are controlled by a single set of levers located just above the main hoisting engine, where the operator can see all parts of the dredge and the bucket.

The dredge is designed to use a 16-ton bucket in ordinary service or a still heavier one for hard digging. It is about one-fourth smaller than other dredges of equal capacity. Special care has been taken to arrange the machinery as compactly as possible and to simplify it, thus securing a machine that is claimed to be exceptionally cheap and convenient in its operation. It has been developed and is manufactured by Toomey Brothers, submarine contractors, of Guilford, Conn.

The Warming and Ventilation of Hospitals.

By Charles L. Hubbard.

The best system for warming and ventilating a hospital depends upon the character and arrangement of the buildings. It is desirable in all cases to do the heating from a central plant rather than to carry fires in the separate buildings, both on account of economy and for cleanliness.

In the case of small cottage-hospitals with two or three buildings placed close together, indirect hot-water affords a desirable system for the wards, with direct heat for the other rooms; but where there are several buildings, and especially if they are some distance apart, it becomes necessary to substitute steam, unless the water is pumped through the mains. For large city buildings, a fan system is always desirable. If the building is tall compared with its ground area, so that the horizontal supply ducts will be comparatively short, the double-duct system may be used with good results. Where the rooms are of good size and the number of supply flues not great, the use of supplementary heaters at the bases of the flues makes a satisfactory arrangement. Direct radiation should never be used in the wards when it can be avoided, even in connection with an independent air-supply, as it offers too great an opportunity for the accumulation of dust in places which are difficult to reach. It is common to provide from 80 to 100 cu. ft. of air per minute per patient in ordinary wards, and from 100 to 120 cu. ft. in contagious wards.

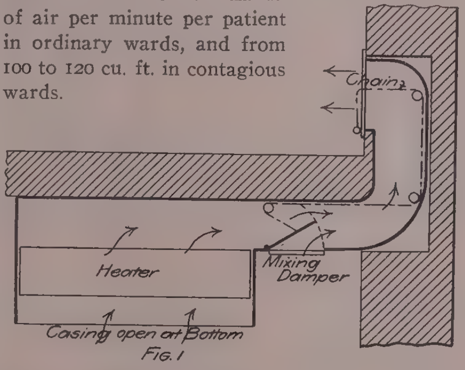


Fig. 1

Stack Arranged With Uncovered Steam Pipes.

The usual ward building of a modern cottage-hospital generally contains a main ward having from 8 to 12 beds, and a number of private rooms with one bed each. In addition to these, there is a diet-kitchen, duty-room, toilet-rooms, bathrooms, linen-closets and lockers.

For moderately sheltered locations, 30 sq. ft. of indirect steam radiation has been found sufficient in zero weather for a single ward with one exposed wall and a single window, when upon the south side of the building. For northerly rooms, 40 sq. ft. should be used. In exposed locations the heaters may be made 40 and 50 sq. ft. for south and north rooms respectively. The standard-pin radiators, rated at 10 sq. ft. of heating-surface per section, are commonly used for this purpose. In case hot-water is used, the same number of sections of the deep-pin pattern, rated at 15 sq. ft. each, may be employed, making a total of 45 and 60 sq. ft. per room. For corner rooms having two exposed walls and two windows, the amount of radiation should be increased about 50 per cent. over that given above.

In the case of the main wards, each bed should be treated as single room with one exposed wall, unless the ratio of wall and window surface per bed is greatly out of proportion.

The warm air in both large and small rooms is usually admitted through wall registers placed just below the windows. One of the most satisfactory arrangements for the cold-air supply to the heaters beneath the main ward is to use the whole basement as a cold-air chamber, with inlets upon both sides. The heating-stacks are suspended at the ceiling and provided with casings having open bottoms and taking their air-supply directly from the basement. The air-supply to the heaters for the private wards may be taken from the cold-air chamber under the main ward, or they may have seperate inlets from out of doors, as is most convenient. In any case there should be at least 3 sq. in. area in the ducts for each square foot of radiation in the heaters. The steam mains and branches to the stacks are left uncovered, and so supply enough heat to produce a layer of warm air at the ceiling, and thus prevent the floor above from becoming chilled. Fig. 1 shows a stack arranged in the manner described. The cold-air inlets to the basement air-chamber should be furnished with cloth checks, and the total opening required should be provided on each side of the building.

The warm-air ducts exposed in the basement, and the back and sides of the flues running up in the outside walls should be covered with an inch of good insulating material, such as seaweed quilting or plastic asbestos or magnesia. If the quilting is used, that portion exposed in the basement should be covered with canvas. The area of the warm-air flues should be about 100 sq. in. for each bed. A 6x16-in. flue is commonly used in single rooms. The wards are usually provided with fireplaces, and these may be utilized for the discharge ventilation. The flues should not be less than 8x12 in. for single wards, and the equivalent for each bed in the large ward. Each flue used for this purpose should have a loop of steam pipe for producing a draught. A loop of 1-in. pipe, 10 or 12 ft. high, is usually sufficient for this purpose. It should be brought into the flue above the throat of the fireplace, and if made of extra-heavy pipe will not be injured by the heat from the fire. If there is a fire-place in the large ward it should be of ample size and provided with an aspirating coil. In wards containing 10 or 12 beds good results have been obtained by providing a fire-place at one end, having a flue area of about 4 sq. ft., with an aspirating coil containing 20 sq. ft. of heating-surface, in the form of a return-bend coil placed in an inclined position on its side across the flue. Another vent of the same size should be provided at the other end of the ward, preferably near the ceiling; this is especially for summer use, but may be used at other times when the fire-place does not prove sufficient. Adjustable shut-off dampers should be placed in each of the vents and provided with chains for operating from the floor. Small wards having no fireplace should have a galvanized-iron vent-flue with a connecting register near the floor. Other rooms, such as diet-kitchen and bathrooms, should have vent-flues of about 1 sq. ft. area each. All vents, except fireplaces, should be gathered in the attic space and connected with one or more main vents passing through the roof. The roof ventilators may have an area of from 0.7 to 0.8 of all the flues connecting with them, and should be provided with suitable cowls or heads, and shut-off dampers which can be operated from the floor beneath. The vents from the small rooms should be provided with steam loops the same as the fireplace flues.

Other rooms than wards are usually heated with direct radiators, the size of which may be computed in the same manner as for dwelling-houses. The operating wing may be treated in a similar manner to the wards. Sufficient air should be provided in the operating, etherizing, and recovery rooms to change the entire contents at least ten times per hour. The radiating-surface for heating and ventilating may be computed by the methods given in connection with school-house work which were printed in last week's issue, allowing an efficiency of 500 B. t. u. for steam and 400 B. t. u. for water, under these conditions.

The large window and skylight in the operating-room is usually made with double sashes, and one or two lines of 1¼-in. pipe should be run around the perimeter between them. A high-speed electric fan, 12 or 15 in. in diameter, for a small operating-room, placed near the ceiling and discharging into an outboard vent-flue, is very useful for clearing the room of ether during or after an operation.

Steam-tables for the kitchen sterilizers, and laundry machinery require a higher pressure than is necessary for heating.

If the grade of the different buildings is such that the entire heating system can be run with a gravity return to the boilers, it is best to do so and employ a separate high-pressure boiler for other purposes. A laundry mangle requires from 60 to 80 lb. pressure to operate successfully; sterilizers 25 to 30 lb, and steam tables 10 to 15, although 5 lb. is often sufficient for this purpose if the supply-pipes are made of ample size. A good arrangement for small plants is to provide sufficient boiler power for warming and ventilating purposes, and run it at a pressure of 3 to 5 lb. In addition to this a small high-pressure boiler carrying 70 to 80 lb. should be furnished for laundry work and water heating. Steam at 25 or 30 lb. pressure for sterilizers and steam-tables may be obtained by the use of a reducing-valve, and the small amount of condensation trapped to the sewer.

In the case of large institutions the entire boiler plant may be run at high pressure, and reduced as required for the different purposes. When this is done, each reducing-valve must have its corresponding trap in the return, discharging into a vented receiver, from which the condensation is pumped back to the boilers automatically. Where the buildings are much scattered, high-pressure steam may be carried in the mains and each building provided with its own reducing-valve and trap; the trap from each building discharging into a common main leading to a vented receiver. With systems like the above, carrying a high pressure, it is necessary to maintain a sufficient pressure day and night to operate the pumps, or the return will become filled with water.

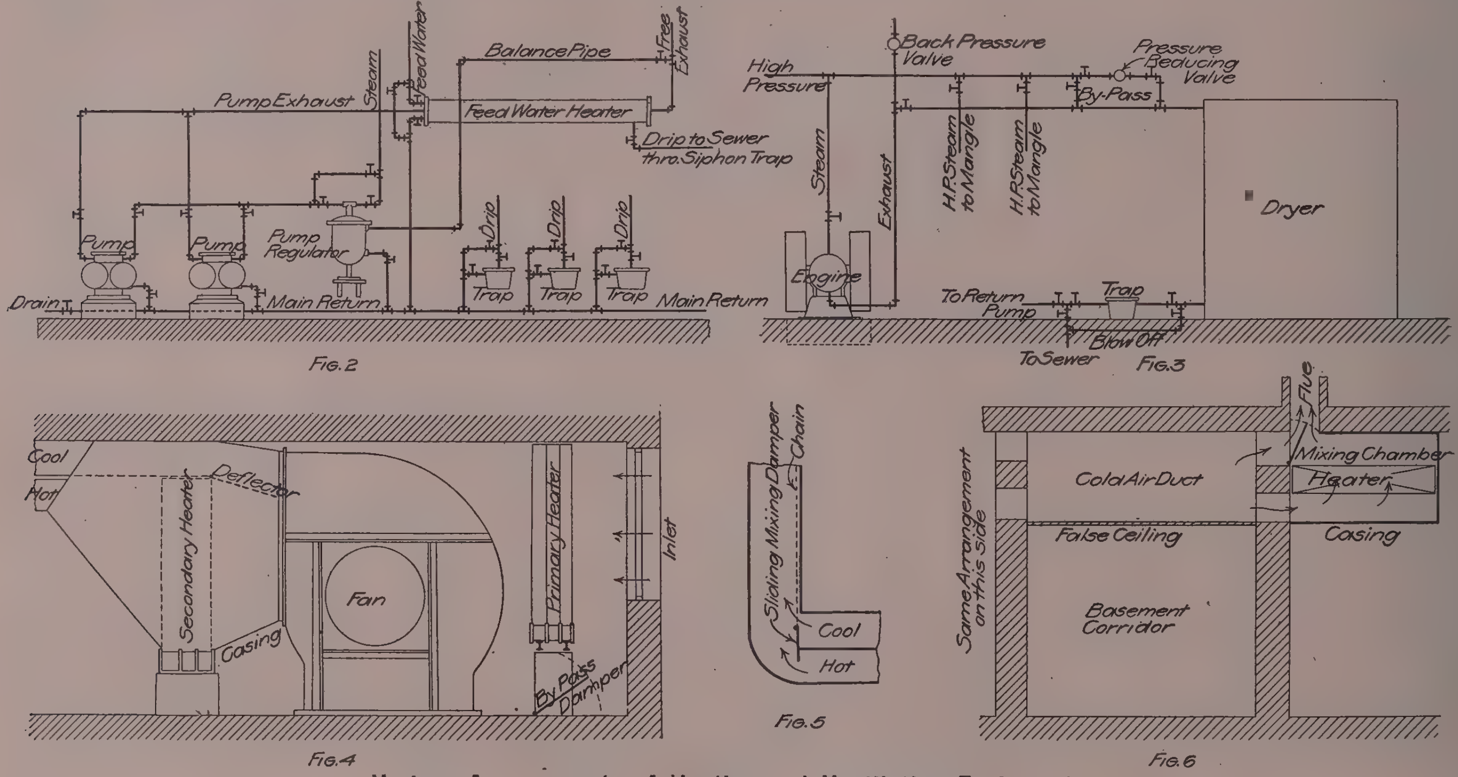


Fig. 2 Fig. 3 Fig. 4 Fig. 5 Fig. 6

Various Arrangements of Heating and Ventilating Equipment.

When the buildings differ in elevation, it is necessary to establish false water-lines in the different buildings by the use of water-line traps discharging into a vented receiver located in the boiler-room.

Sometimes the buildings can be grouped so that one water-line trap will care for several of them. Each building should be separately connected with the mains, and provided with valves, so it can be shut off in case of accident or repairs. An arrangement for making the return connections without the use of a receiver is shown in Fig. 2. In this case all traps discharge into a return main, which is vented through the balance pipe of a pump regulator into the outboard exhaust.

This method of making the return connections is only adapted to cases where all of the returns are under practically the same pressure. Otherwise there will be danger of water-hammer when traps under a higher pressure discharge into the cooler water of the main return. When the different traps discharge into a vented receiver above the water-line, all trouble of this kind is avoided.

The exhaust from the laundry engine should be turned into the drying coils, with a connection for admitting high-pressure steam through a reducing-valve, as may be necessary to make up the full amount required. The trap on the return should be arranged so as to discharge either to the receiving-tank or sewer according as live steam or exhaust is used. Fig. 3 shows a typical arrangement for laundry piping.

The necessary boiler power for heating water for laundry, kitchen, and bathing purposes may be taken as one horse-power for each five inmates, including both patients and attendants.

In large buildings where the double-duct system is employed, all of the air is heated to the maximum required to maintain the desired temperature in the most exposed rooms, while the temperature of the other rooms is regulated by mixing with the hot air a sufficient volume of cold or tempered air at the bases of the different flues. This result is best accomplished by designing a hot-blast apparatus so that the air shall be forced, rather than drawn, through the heater, and by providing a by-pass through which it may be discharged into the ducts without passing over the heated pipes.

The quantity of heat required per room may be computed by first finding that necessary for ventilation, and adding to it the amount required to offset that lost by conduction through walls and windows. The temperature to which the air must be raised to warm the coldest rooms may be determined as follows: Select one having the greatest wall-exposure compared with the number of occupants and first compute the quantity of heat necessary to raise the required volume of air for ventilation from zero to 70° Fahr. Next determine the heat loss by conduction through walls and windows, and find to what final temperature the air must be raised in order to furnish this additional quantity of heat. This process can best be shown by working a practical example: The air-supply to a ward is 12,000 cu. ft. per hour, and the heat loss through walls and windows is 10,000 B.t.u. per hour. To what temperature must the entering air be heated to warm the room, and what will be the total heat required for both heating and ventilation? The heat required for ventilation, that is for raising the air-supply from zero to 70° Fahr. is $(12{,}000 \times 70) \div 55 = 14{,}000$ B.t.u., nearly, and the total heat required is $14{,}000 + 10{,}000 = 24{,}000$ B.t.u. The question now becomes, to what temperature will 24,000 B.t.u. raise 12,000 cu. ft. of air? This may be found by the formula: $(\text{B.t.u} \times 55) \div \text{cu. ft. of air} = \text{rise in temperature}$.

Substituting the quantities in the problem in the above, we have $(24{,}000 \times 55) \div 12{,}000 = 110°$ Fahr., which is the temperature to which the above quantity of air must be raised in zero weather.

Referring to Table 1, we find that with steam at 5 lb. pressure, the heater must be 16 pipes deep in order to raise the entering air to this temperature in zero weather, and that the efficiency under these conditions will be 1,400 B.t.u. per square foot of surface per hour.

The heater must then be proportioned to warm, say, 80 per cent. of the entire air supply of the building up to this temperature.

Instead of mixing the hot with the cold outside air, for the rooms requiring less heat, it is better to first draw all of the air through a primary or tempering coil, raising it to a temperature of 55 or 60° Fahr., and then make the secondary heater of sufficient size to raise it to the desired maximum. When this arrangement is used, the first heater may be made 7 or 8 pipes deep, and the second of sufficient depth to bring the total up to the number required. In the present case, both heaters would be made 8 pipes deep. The total heating-surface may be computed as though it were all placed in one heater. Each unit should have practically the same free area for the passage of air through it, although only a part passes through the secondary heater.

Table I.—Temperature to Which Air Will Be Raised and Efficiency with Different Steam Pressures.

Rows of pipe deep.	Temp. to which air will be raised from zero with steam pressures in heater of 5 lb.	20 lb.	60 lb.	Efficiency of heating surface in B.t.u., per sq. ft. per hr., with steam pressures in heater of 5 lb.	20 lb.	60 lb.
4	30	35	45	1,600	1,800	2,000
6	50	55	65	1,600	1,800	2,000
8	65	70	85	1,500	1,650	1,850
10	80	90	105	1,500	1,650	1,850
12	95	105	125	1,500	1,650	1,850
14	105	120	140	1,400	1,500	1,700
16	120	130	150	1,400	1,500	1,700
18	130	140	160	1,300	1,400	1,600
20	140	150	170	1,300	1,400	1,600

Fig. 4 shows a typical arrangement of fan and heaters, and Fig. 5 a common form of mixing damper for use at the base of the flues. In the best equipped plants, graduated mixing dampers operated by automatic means, controlled by thermostats, are used in place of hand dampers.

When supplementary heaters are used at the base of the flues, a main or primary heater of sufficient size should be provided to raise the air to 60 or 65° Fahr., and the secondary heaters proportioned the same as in school-house work; that is, made one-half as large as direct radiators would need to be if placed in the rooms.

Fig. 6 shows a layout where the upper part of the basement corridor is used for an air duct, with secondary heaters placed at each side.

Waiting-rooms, corridors, and silmiliar parts of the building are usually heated by direct radiation, but should be provided with vent registers connected with the general discharge ventilation.

In large hospitals, where a supply fan is used, an exhaust fan of either the disc or steel-plate type is usually employed for removing the air from the building, instead of relying upon natural draft. This makes it possible to use smaller flues and results in the saving of valuable space, which is always a matter of importance in large city buildings. The exhaust fan is generally proportioned to remove about three-fourths of the air supplied to the building, leakage being depended upon to care for the remaining portion. The flues may be connected with centrally located chambers in the roof or attic space by means of galvanized iron ducts, and one or more fans, depending upon the size of the building, used for discharging the air outboard through properly protected hoods.

Direct-connected electric motors are used for driving the fans whenever a direct current is available, otherwise, belted motors must be used.

Insane asylums are necessarily heated by hot-air and a fan is generally employed for this purpose. The flues are carried up in the brick walls, and should, if possible, be provided with terra-cotta linings. Very good results may be obtained by grouping the rooms according to the outside exposure and furnishing air at the same temperature to all of the rooms in one group. About three complete changes of air per hour are allowed for the rooms, and it is heated at the fan to a temperature sufficient to warm those which are the least exposed. Supplementary or reheaters of proper size are placed in the branches leading to the more exposed sections of the building. The whole apparatus is operated from the basement under the control of the engineer.

Fuel Oil is to be abandoned on the torpedo boat Gwin, of the U. S. Navy, after a thorough trial lasting a year. The best speed obtainable with oil for fuel was about 16½ knots, while a boat of duplicate construction, fitted for burning coal, shows a speed of 20 knots.

The New Cincinnati Water Works.

A number of descriptions of various parts of the water works improvements that have been under construction in Cincinnati for several years have been published from time to time in this journal. A concise and authoritative statement regarding these improvements was presented recently before the Central States Water Works Association by Mr. George H. Benzenberg, acting chief engineer to the Board of Trustees of the Commissioners of Water Works of Cincinnati. Mr. Benzenberg's statement was supplemented by a somewhat detailed outline of the plans for the filtration plant that is a part of these improvements, by E. C. Manahan, assistant engineer in charge of the construction of the filtration plant. The following notes regarding these improvements have been taken from these two authoritative statements, the first that have been made public.

The existing water works of Cincinnati consist of quite a number of pumping stations; first, the main pumping station at Front St., where the water is taken from the river, and delivered first into a low-level reservoir called the Third St. reservoir, from which is supplied all the territory along the river front below Fourth St., the Mount Hope pumping station, which delivers water up into Price Hill and Fairmount Hill, and also the pumping station for Westwood. The pumps at the Front St. station deliver water into Eden Park reservoir, which consists of two basins of an aggregate capacity of about 100,000,000 gal. The Eden Park reservoirs supply what is called the middle service, or the territory throughout the business district in the Millcreek Valley out along the eastern end of the river from Front St. eastward, to the city limits. The territory up in the hills, all the high districts in the city outside of Westwood, Price Hill and Fairmount, which is on the west side of Millcreek, is supplied by two pumping stations, one located at Eden Park, taking its suction direct from Eden Park reservoirs, and delivering the water directly into the system through a standpipe; the other, an older station, which delivers water to the high-service district, is the Hunt St. station, taking its supply out of a 35-in. main leading from the Eden Park reservoir down into the middle district, or the upper middle territory comprising the business district. Another pumping station for the purpose of supplying College Hill and higher territory at Cumminsville, was located west of Millcreek in Cumminsville, and took its supply from the middle service, delivering into a separate distribution system which was carried out as far as College Hill. Still another pumping station was located at Linwood, taking its supply out of wells, and delivering water into the northeastern part of the higher districts of the city. The territory called Bond Hill was until quite recently supplied from the St. Bernard water works, which is outside of the city.

The new works contemplate practically concentrating all these various plants into two; one located at California, a distance of about 6 miles above the old pumping station, and a short distance above the Covington, Ky., pumping station. The water is taken out of the river at that point and then delivered into settling basins, and filter plants through a tunnel, to the main pumping station located on Eastern Ave., at the foot of Torrence Road, at which point the engines are to be located for delivering water into the present low and middle service, doing away with the existing low service. A set of engines will also deliver water directly from there into the high-service district, so that the main pumping station will furnish water for all parts of the city, both high, low and middle service, excepting a certain part which is west of Millcreek which will be supplied by a separate small station, called the Western Hill station, located on Queen City Ave. Consequently, the operating expense will be very materially reduced by the new arrangement when put into service.

The water is proposed to be taken from an intake located very near to the Kentucky shore opposite the pumping station, where a stone intake pier has been constructed with a shaft reaching down to about 65 ft. below datum, there connecting with a tunnel passing under the river bed a length of 1,400 ft. to an uptake shaft on the Ohio side, which forms the supply for four 30,000,000-gal., triple-expansion pumping engines located around the uptake shaft in a pump pit. The intake is provided with ports at several levels, so that the water can be taken at any stage, and is provided with sluice gates and screens. The screens are of sufficient capacity and area to reduce the velocity of flow under maximum conditions to the minimum. The tunnel is 7 ft. in diameter, located and constructed in stratified lime formation backed with concrete and finished with two rings of specially burned vitrified brick. This tunnel, 7 ft. in diameter, leads to a shaft, on the Ohio side, of 10 ft. in diameter, which in turn passes through a pump pit 85 ft. in depth below the surface of the ground, the top of the pit being but a few feet above the highest stage of the water on record, and the bottom of the pump pit being about 6½ ft. below datum, or about 10 ft. below the lowest stage of water in the river.

The four 30,000,000-gal. engines are grouped around within this pit, which is 98 ft. in diameter in the clear. The engines are protected by a circular stone pumping station building to which is attached an annex to cover the auxiliary machinery necessary. There is a stone boiler-house capable of taking care of the boilers and other machinery necessary to operate the plant. From these four 30,000,000-gal. pumping engines, 48-in. discharge mains are run to the outside of the building, connected with two 60-in. mains running along a constructed pike up to a point between the two settling reservoirs, which are located up in the hills at an elevation of about 145 ft. above datum. The mains rise from the point of connection with the 48-in. discharge mains continuously till they get to a discharge weir and circulating chamber from which the water is discharged into either basin.

The basins have been constructed to conform as much as possible with the contour of the ground. They form the bed of two ravines which are closed off by two dams, the one on the upper and the one on the lower basin coming together at a point dividing the two original ravines or basins. The capacity of Reservoir No. 1 is 158,000,000 gal., and that of Reservoir No. 2, 187,000,000 gal.

Reservoir No. 1 is very near completion and the expectation is to fill that basin some time this fall. By-pass pipes 60 in. in diameter are provided, so the water can be discharged into the coagulating basins without passing over the settling basins at such times as the river water is in fair condition in carrying a very low percentage of sediment. Provision is made for drawing the water from these basins within 2 ft. below the water surface. There is a conduit which carries the 60-in. main up into an up-take shaft whence the mains are carried over to three coagulating basins where they are led into one or the other of these three basins, two of which have a capacity of 10,000,000 gal. each, and the remaining one of 2,000,000 gal. As the water passes to either basin it receives the proper coagulant in such percentage of solution as the condition of the water at the time may require. The water passes through the coagulating basin out on the opposite side, and then into the filter house, and from the filter into a clear water storage basin of about 18,000,000 gal. capacity. The water is passed in on the top and then drawn out near the bottom of this basin, passing through a large steel conduit and into a shaft connecting with a gravity tunnel. This shaft at this point is perhaps 180 to 190 ft. in depth, and connects with a tunnel constructed at an elevation of about 70 to 75 ft. below city datum, and 80 to 85 ft. below low water in the river through a similar stratified limestone formation as was found in the tunnel crossing under the bed of the river. The design and construction of this tunnel, which is about 4¼ miles in length, were fully described in The Engineering Record for March 4, 1905. It extends to the main pumping station on Eastern Ave., and is of similar construction to the one under the river. On a test after the tunnel was completed and cleaned out, the infiltration through its entire length was between 9 and 10 gal. per minute, or about 13,000 gal. per 24 hr. In fact, in passing through the tunnel after it was cleaned and finished, Mr. Benzenberg says there was nothing noticeable anywhere excepting just drippings, sweating through the brick and some of the joints, which on the entire length amounted to the small quantity noted. The tunnel was also tested under a head, not quite the head under which it will be operated, but as nearly so as it could be. The filtration or leakage out of the tunnel during the test at the high stage of water that could be put into the tunnel at the time, was about the same as the infiltration. Mr. Benzenberg thinks this tunnel will be operated under a greater head than any other water tunnel constructed up to the present time. The head when the clear water basin is full will be something like 175 ft., minus whatever stage of water the river may take.

At the main pumping station a space is provided for eight 25,000,000, and four 12,000,000-gal. pumps, three of which in each service are now being installed, one of them being ready for service. The water will be delivered through a 60-in. main along Eastern Ave. to a point very nearly opposite the present Eden Park reservoir, where the supply will be connected with a 46-in. and 36-in. main discharging into Eden Park reservoir. The water, as will be remembered, must all now pass through Eden Park reservoir to be supplied either to the middle service or to the high service. There is no direct connection from the pumps into the distribution system. Under the new arrangement water will be mainly delivered into the middle service or into all the lower business district direct, the surplus pumpage over the consumption flowing into Eden Park; which will enable the operation of the pumping machinery at a uniform speed throughout the twenty-four hours, the reservoir acting more as an equalizer, taking up the surplus pumpage during the night, and giving off what is necessary to meet the consumption during the day. The high-service pumps are connected by a 48-in. main running up what is called Humboldt Ave., and are connected to Woodburn Ave. with a 36-in. main running in either direction, connecting direct with the present distribution system, having no possible chance of supply except what is called the two Mt. Auburn tanks, which have a combined capacity when full of about 1,250,000 gal. The distribution system throughout the city has been very inadequate to meet the demands of consumers either in quantity of water or in pressure in the outlying districts. An attempt has been made to improve the distribution system, and something like between $500,000 and $600,000 have been expended in that direction. One of the principal mains of this attempted improvement was a 48-in. pipe constructed from the eastern part of the business section of the city up Ninth St., and continuing out to the extreme northwestern part of the city into the low territory surrounding Millcreek, which also will be used for supplying the Western Hills station. The Western Hills station, which is located in the valley formed by Price Hill and Fairmount Park, will take its supply directly out of a 30-in. main, and will contain two 2,500,000-gal. pumps, and a little later on two 1,000,000-gal. pumps; the two 2,500,000-gal. pumps supplying water in the Price Hill tank, and doing away with the Mt. Hope pumping station, delivering water into the West Hills, or Westwood, to the high territory, which will be built up here and become part of the city, lying particularly between Westwood and College Hill.

The capacity of the new works is sufficient to meet the reasonable demands of a population of about 1,000,000. If meters are generally introduced, possibly the population may reach to a million and a quarter before any additional installation will be required, except the installation of one additional high-service 12,000,000-gal. pump at the Western station, and one middle-service, 25,000,000-gal. pump, for which space is left both in the foundation and in the boiler house.

Conditions Governing Filtration.—Mr. Manahan, in speaking of the conditions governing the filtration of the supply, said that the water of the Ohio River at Cincinnati is in its natural or raw state undesirable as a source of domestic water supply; both on account of its turbidity, and on account of its pollution by sewage. The water is very muddy during more than one-half the year; the turbidity then amounting to from 200 to 2,000 parts of suspended matter per million. The river often rises at a rate of 5 to 10 ft. per day, and the amount of suspended matter and the nature and size of the suspended particles change with the rate of rise, making the turbidity quite variable in quantity and quality.

The amount of sewage pollution is quite considerable. The number of people living in cities upon the watershed of the river above this city is about 30 per square mile. This number is about the average for cities having badly polluted water supplies, such as Philadelphia, Albany, Pittsburg, Toledo and New Orleans, for which filter plants have been or are being provided. The effect of sewage pollution is greatly reduced by the dilution due to the large volume of flow, and in addition much of the organic impurities become settled out in their passage down the river. The number of bacteria, however, averages as high as 20,000 per cubic centimeter, and at times runs above 100,000. Bacteria of sewage origin are found nearly always in the water from the present city intake. Except for that portion of its own population which is located above the present intake, the city is situated at a considerable distance below any large source of sewage pollution; and it is therefore expected that when water is taken from the new intake, seven miles up stream from the old one, the sewage bacteria will largely disappear.

Aside from its turbidity and sewage pollution the water of the Ohio River is of good quality for water supply. It has no disagreeable odor and very little color except that due to turbidity. It is only moderately hard, and is a good water for boiler purposes. Except for the earthy taste at time of high turbidity, the water has an agreeable taste. It is therefore the object of the filtration plant to remove, as far as possible, all turbidity and effects of sewage pollution.

Type of Filtration.—The type of filtration determined upon was made necessary by the requirements for removal of turbidity. Experiments were made several years ago by the Water Commissioners under the direction of Mr. George W. Fuller, in regard to the practicability of various methods of purification. From these experiments it was learned that during periods of freshets, lasting generally during a total of about one-third of the year, a slow sand filter, although treated with water which had been settled for three days, would give a brownish colored effluent. The bacterial efficiency of the slow sand filters was also found to be decreased by long periods of operation under excessive turbidity. Experiments showed that rapid mechanical filtration—that is rapid filtration through sand after the application of a coagulant—was applicable to the Ohio River water, both as to efficiency and cost of operation, so this method was therefore adopted.

Method.—The method of treatment adopted consists of three stages; first, plain subsidence for two or three days; second, coagulation and sedimentation; and third, filtration. By the plain subsidence it is expected, Mr. Manahan said, that from 40 to 80 per cent. of the suspended matter can be removed, and also an average of 50 per cent. of the bacteria. By coagulation and sedimentation from 50 to 90 per cent. of the remaining suspended matter and bacteria can be removed; and, by filtration, all the remaining suspended matter and bacteria except possibly about 1 per cent. of the total original amounts will be removed.

Capacity of Plant.—The total capacity of the plant is 112,000,000 gal. per day. This capacity is much greater than that of any plant of the same type now in operation, or projected. The largest mechanical filter plant now in operation is that of the East Jersey Water Co. at Little Falls, N. J., which has a capacity of 32,000,000 gal. daily, although the latter plant is of somewhat different design from the Cincinnati plant.

Settling Reservoirs.—The first step in the process of purification is plain subsidence. For this purpose, two settling reservoirs, having a combined capacity of about 350,000,000 gal. are in process of construction, one of them being nearly completed at the present time. Water will be drawn from one of these reservoirs while the other is being filled. The time of subsidence, under conditions of maximum consumption, will thus be about one and one-half days. The settling reservoirs are not a part of the filtration plant proper and will not be further referred to here. Their construction is under the direction of Mr. W. C. Jewett.

Coagulation Basins.—At the filtration plant there will be three coagulation basins; two having a capacity of 10,000,000 gal. each, and the third a capacity of 2,000,000 gal. The subsided water from the settling reservoirs, after the addition of coagulant, will pass to these basins. The latter will be operated on the continuous method, the water entering at the bottom through a series of openings at one side, and passing continuously upward and across, and out at a corresponding series of openings at the top on the opposite side. The coagulation basins may be used either singly or in combination; thus enabling the period of time of sedimentation to be varied within considerable limits. The connecting piping is so arranged that secondary coagulation and sedimentation may be produced by making a second application of coagulant to the water which has already been treated in either or both of the two large basins, and then passing the water back through the third or small basin, in the reverse direction from that in which the water normally flows. The sludge which settles to the bottom of the basins will be removed by flushing with a hose after drawing down the water in the basins. At times when the river water is comparatively clear, water can be pumped directly from the river to the coagulation basins, if desired, thus saving the extra cost of pumping to the higher level of the settling reservoirs.

Filters.—There will be twenty-eight filters, each having a capacity of 4,000,000 gal. of filtered water per day. Each filter will contain a 30-in. layer of sand and an 8-in. layer of gravel, through which the water will pass downward at the rate of 3 in. per minute. The sand and gravel for the filters will be taken from the Ohio River near the filter site. The finer particles will be washed out of the sand before it it is placed in the filters, in order to obtain the proper effective size.

The gravel will rest directly upon a series of rows of perforated brass plates, called the strainer system; underneath which are numerous concrete channels and pipes leading from the filter, so arranged that the water will flow from all parts of the filters with equal facility. After a filter has been in service for a period of from six to twenty hours, it will become clogged, and will then be washed by forcing a volume of filtered water backward up through the sand, and draining the water containing impurities over weirs at the top of the filter. In washing the filters no agitating devices, such as rake arms, or the use of compressed air which is common in the latest filter plants, will be used. Instead, the wash water will be forced in at a very high rate; about two and a half times that customary in similar plants. This method is said to have been found by Mr. Ellms, chemist for the water commissioners, who originated the process, to give a more thorough and uniform agitation than has been otherwise accomplished.

Head House.—At one end of the house containing the filters, there will be a building called the head house through which the subsided water from the settling reservoirs will first pass, and where the coagulant will be applied before the water passes to the coagulation basins. In this house there will also be appliances for measuring the water passing to the coagulation basins and for controlling its pressure, and centrifugal pumps, for pumping the water used for washing the filters, to a small reservoir on a nearby hill. One-half of the house will be occupied by laboratories and offices for the administration forces.

Chemical House.—At the other end of the house containing the filters there will be a building known as the chemical house, in which the solutions of coagulant will be prepared. A railroad siding will enter the house, and storage will be provided for about a month's supply of chemicals. A room will be set apart for the boilers of the heating system of the houses of the plant.

Sulphate of iron and lime will be used to produce coagulation. The plant is designed to be capable of putting into solution and applying quantities of iron up to two grains, and of lime up to three grains per gallon of the maximum capacity of the plant, 112,000,000 gal. At these maximum rates about 24 tons of lime and 18 tons of iron per day would be used. The lime and iron will be brought into the plant in bags of 100 lb. each.

The apparatus for preparing the iron will consist of a series of five tanks of a capacity of about 1,800 gal. each, which while in operation will be always kept full of the solution, and in which the solution will be kept in continuous circulation by means of propeller pumps. At given intervals of time bags of sulphate of iron will be dumped into the tanks, where the iron will be dissolved by the agitation produced by the circulation of the solution. In order to keep the solution at constant strength water will be passed into the tanks at a uniform rate. As fast as the water runs into the tanks, the solution of sulphate of iron will flow out over an overflow, and pass to its point of application to the subsided water in the head house.

In preparing the lime solution a ten per cent. milk of lime will first be produced, which will be afterwards converted into a lime-water solution. The method of obtaining a milk of lime of uniform strength will be much the same as that used in the case of the iron solution, that is, the insertion into the slacking tank of a bag of lime at the end of each given interval of time; the continuous addition of water at a uniform rate, and a continuous outflow of the milk of limt at the same rate. The water for slacking the lime will first be heated to about 120 Fahr. by hot-water heaters. The entrance of lime dust into the room will be prevented by a ventilated hood, provided with an exhaust fan beneath which the lime is dumped. There will be six slacking tanks about 6 ft. in diameter by 3 ft. high, of which three are to be in reserve for the purpose of cleaning. Slacking is to be promoted by a set of stirring arms. From the slaking tanks the milk of lime will pass to the lime saturators, of which there will be four, each being about 18 ft. inside diameter by 24 ft. high to the water line. One of the saturators is to be in reserve for cleaning. The water which is to be saturated with lime will form about 5 per cent. of the capacity of the plant; and therefore settled water, not filtered water, will be used. The water is regulated by means of a rate controller so as to enter at the uniform rate of flow. The milk of lime will enter the saturator through the same pipe, and both will pass downward together through a flaring tube to the bottom of the saturator. At that point their direction will be reversed and they will rise and pass over a weir at the top. In passing downward into and upward through the saturator, which will take about 35 minutes, the water will have become saturated with the lime and the two will pass out over the weir as lime water. The lime water will be applied to the main body of water just before it enters the coagulation basins, and about 50 ft. below the point of application of the iron solution. An agitating device at the bottom of the saturator will prevent the milk of lime from settling and remaining at the bottom of the saturator. Provision is also made to clean out the sludge in the bottom of the saturator by opening quickly a plug in the bottom and causing a sudden outflow of the water.

Clear-Water Reservoir.—To balance the supply from and the demand upon the filters, a clear water reservoir of about 20,000,000 gal. capacity is nearly completed. Although it is anticipated that a growth of micro-organisms may occur in this reservoir, due to the exposure of the water to sunlight, it is not intended to cover the reservoir until it is found necessary. Provision has been made in the design for readily doing this. Experience in other places has shown, Mr. Manahan said, that filtered water may be stored with safety for a week or two in open distributing reservoirs.

Construction of Basins.—The basins and reservoir are formed partly in excavation and partly in embankment. For tightness and for wearing purposes they will be lined inside, first with rolled clay, from 2 to 4 ft. thick followed by concrete and vitrified brick. The concrete will be in a layer about 6 in. thick, cut into squares of about 10 ft. on a side by means of grooves which are to be filled with asphalt to make expansion joints. Between the concrete and brick will be a layer of asphalt about ¼ in. thick, and held in position on the slopes by means of burlap.

Buildings.—For the foundations of the various buildings concrete has been used for the floors, the roofs and for some of the partitions. The filters are to be monolithic boxes of reinforced concrete, 50x32 ft. in plan inside, by about 11 ft. high. All of the tanks for coagulants are to be of concrete except the slaking tanks, which will be of steel. Some river gravel with river sand and also some crushed limestone and bank sand are being used in this concrete. The superstructures of the buildings are to be faced outside with Sienna colored pressed brick with trimmings of Rock Castle free stone. Some of the small valve houses will have red tile roofs and buff terra cotta trimmings in part. The inside of the filter house will be faced with white Kitanning brick.

All pumps, stirring machinery, and all valves above 16 in. in diameter, will be electrically operated, although provision will be made to enable them to be operated by hand. There are to be 170 electrically-operated valves in all, of which eleven will be 84 in. and eleven, 60 in. diameter.

The Importance of River Gaugings.

The importance of river gaugings conducted systematically over the whole country was briefly mentioned in this journal on Sept. 29, when the desirability of affording private assistance in such work to the U. S. Geological Survey was explained. Those people who believe that the failure of Congress to provide for continuing the gaugings will not be at all serious should read the following statement contributed some time ago to the "Michigan Engineer" by Mr. Robert E. Horton: "There are various reasons why systematic stream gauging should be done by the Federal government. A river usually passes over or adjacent to the lands of many owners. The results of gaugings of the stream may be of value to ordinary riparian owners and to those who have large interests in the water power, or other resources of the stream. The larger interests and corporations often make gaugings on their own account, but others seldom have the means or facilities at hand for such work. The results should, therefore, be made public whenever possible, so they may be equally available to all. There are also many interstate streams, and questions of the right of diverting or polluting such streams frequently arise between adjacent States. It is desirable that the commercial value of the stream and its waters should be impartially determined. Questions of the further development of streams by the construction of storage reservoirs are attracting widespread attention. Oftentimes such storage reservoirs would be located in one State whereas the principal benefit would be derived from them by riparian owners in another State. As the development of the country and the value of the land increase, foresighted measures to increase the utility and prevent the abuse of water resources will become necessary. As a preliminary step, reliable gaugings of the streams covering periods of several years, are of the greatest importance. The hydrographic branch of the Geological Survey does not wish to undertake work along the line of stream gauging which would naturally be done by private engineers in the interest of particular projects. The object is rather to maintain records covering longer periods of time than are ordinarily covered by private observations. In this way, a standard or basis of comparison of the streams of a region may be obtained which will be a decided help to engineers. For example, suppose it is desired to develop a water power along the course of a river which has been gauged at a point near its mouth for a number of years. The proper course of procedure would be for the engineer of the project to secure a series of gaugings covering a short period of time at the site of the proposed power plant. A comparison of the gaugings so obtained with the simultaneous records at the regular gauging station may then be made. This will often furnish a basis for the estimation of the power at the proposed dam site throughout a much longer period of time than is actually covered by gaugings at that point."

Experience With Intermittent Filtration of Sewage at Worcester, Mass.

The experience gained with intermittent filtration of sewage at Worcester, Mass., extends over a period of such duration that the information recently made public on the subject in a report by Mr. Harrison P. Eddy, superintendent of sewers, is of much value. When the original disposal works, employing chemical precipitation, were constructed, the sewage was characterized by the presence of an unusual amount of iron salts from large works and other industrial establishments, which permitted a satisfactory precipitant to be obtained by adding lime alone. This fortunate condition has been changing, however, and there has been a very material increase during the last few years in the quantity of waste liquids received from various tanning and dyeing establishments. At the same time there has been a slight decrease in the amount of iron received, so that there is not present in the sewage during much of the time enough iron to remove completely the coloring matter due to other chemical wastes. The average amount of lime added in 1905 was 999 lb. per 1,000,000 gal., exclusive of that added to the sludge to facilitate pressing. The average amount of organic matter removed by chemical treatment during 1905 was 51.5 per cent., as shown by the albuminoid ammonia, and the suspended matter has been reduced 85.8 per cent.

About 11.7 per cent. of this chemical effluent is now further purified by intermittent filtration. Some of the precipitation basins have also been run as plain sedimentation tanks and others as septic tanks in order to ascertain how well such methods would prepare Worcester sewage for filtration, and experiments have also been conducted with the filtration of raw sewage without other preparation than passage through a grit chamber.

The first filters, 14 in number, were started in the latter part of 1899. They are each practically one acre in area, 6 ft. deep and under-drained with lines of pipes 52 ft. apart. The effective size of the sand averaged at first a 23 mm. in diameter with widely varying uniformity coefficients. Most of the beds are artificial, having been built upon a swamp with sand from an adjoining bank. The sewage is discharged onto most of the beds from the four corners. These filters have received at various times and in varying amounts chemical effluent, settled sewage, septic effluent and unsettled sewage.

In December, 1903, nine more filters were put into use. These are very similar to the first fourteen in construction, except that they are only 4½ ft. deep and that the sewage is discharged onto each bed from one point only. In three beds, wooden box distributors are provided. The sand used in these beds averaged 0.158 mm. in effective size. These filters received sewage which was passed through one basin 40 ft. wide, 166 2/3 ft. long and 7 ft. deep, at the full rate of the flow in the outfall sewer, during 1904. Throughout 1905 they received the crude sewage direct from the grit chamber.

In December, 1904, four more beds were started, two on sewage and two on chemical effluent.

Filtration of Chemical Effluent.—The amount of chemical effluent filtered on the original 14 beds and the proportion of the area devoted to this, is shown as follows in million gallons:

Year.	Av. per day.	Acres in use.	Av. per acre per day.
1900	0.984	2.92	.337
1901	2.031	7.4	.274
1902	1.583	12.2	.130
1903	1.010	8.9	.113
1904	1.640	12.8	.128
1905	1.180	8.75	.135

A marked reduction in the quantity of effluent filtered per day is very noticeable. It is also important to note that after the second year, while there are some variations in the quantity filtered, the capacity of the filters appears to remain substantially constant. The decrease in the capacity of the filters is undoubtedly largely due to the change in the nature of the material on and near the surface of the filters. The effluent from chemical precipitation invariably carries a small amount, perhaps averaging about 5 parts in 100,000, of very finely divided suspended matter. This material consists partly of organic matter, partly of hydrate of iron. The water also contains considerable sulphate and carbonate of lime in solution, and possibly at times some in suspension. The finely divided suspended matter in the effluent was retained in the upper portions of the sand, forming a layer of material having characteristics entirely different from the original sand.

At times an appreciable amount of lime has been precipitated on the surface of the filter, forming a hard crust, which impeded the passage of water to such an extent that it was necessary to break it up to get a satisfactory quantity of water into the filter. This crust may be broken up with a hand rake, but generally a wire-tooth horse weeder has been used for this purpose. The accumulation of the organic matter and iron in the upper portion of the sand continued to a point where the filter became very slow. At this time the surface was frequently scratched with the weeder to a depth of from 1 to 2 in. The difficulty due to the matter carried in the effluent continued, however, until finally it was deemed necessary to harrow the filters. This method of surface treatment in each case served to mix the fine material with the sand, and for a time increased the capacity. At the same time the increase of capacity was procured at the expense of an increase in the depth to which the iron and organic matter were mixed with the sand. There finally came a time when the filters refused to take a sufficient quantity of effluent to make their further use practical, and it was found necessary to remove the upper portion of the sand which had become mixed with the solids of the effluent. This was three years after the filters were started.

After a quantity of this material, amounting to nearly 4 in. in depth, had been removed, the filters nearly regained their original capacity. This was maintained, however, for a very much shorter period than was the case when the filters were first started, undoubtedly due to the fact that the cleaning had not been carried deep enough to remove entirely the foreign matter which had found its way into the sand.

The experience thus far seemed to demonstrate the inadvisability of mixing the foreign substances with the sand by any process of raking, harrowing or plowing, if it could be avoided. Accordingly, no further disturbance of the surface of the filters was permitted under ordinary conditions, except on one occasion when the surface of the beds had become hard to such a depth that it was found absolutely necessary to resort to plowing.

Since 1903, when 4 in. of the material was removed from the surface of the filters, it has been the custom to remove the surface material at frequent intervals, and in this way maintain the efficiency of the beds rather than by mixing it with underlying clean sand. It is apparent that the best results are obtained when this material is raked up at least twice a year.

Including the very thorough cleaning of the filters in 1903, the amount of clogging material removed averaged up to that time 3.3 cu. yd., measured in the bed, per million gallons of water filtered. During 1904 and 1905 the amount removed has been somewhat less than this, but the indications are that not less than that amount would have to be taken off on the average. The cost of removing this material cannot be estimated at less than 15 cents per cubic yard for raking up, with whatever charge is necessary for disposing of it, depending on the length of the haul. In 1905 the total cost of this work was 40 cents per cubic yard.

The clogging of the filter by the foreign substances brought on with the effluent is undoubtedly due, to quite a large extent, to the reduction in the effective size of the material near the surface of the filter. The amount of this reduction is shown by the analyses made in one of the beds, where it was found that the effective size of the sand in the upper portion of the filter had been reduced from 0.384 mm., when first constructed, to 0.170 mm. four years afterward. This is a reduction of over 50 per cent., and while the effective size at the time of the analyses had not been reduced as low as that of the sand in some of the filters, it shows the extent to which the decrease in effective size may be expected to go. It is undoubtedly true that the clogging is not caused wholly by the reduction in size of the material, but that its character also has a marked effect.

The accompanying analysis of the material removed from the filters gives a very good idea of its composition. Two samples were taken, one over a drain which had been recently relaid, so that the sand was comparatively loose, and the other between two drains where the material had not been disturbed to any depth since the filter was built. The samples represent the top inch of the filters:

ANALYSIS OF TOP LAYER OF FILTER.

	Sample over drain.	Sample between drains.
Moisture	15.3%	11.5%
Loss on ignition	11.9	6.8
Organic nitrogen	0.709	0.325
Calcium oxide	2.2	1.9
Ferric oxide	3.5	3.0

This analysis shows that a very material amount of ferric oxide was found in the top layer of the filter. Analyses of the sand at different depths from the surface to the under-drain have shown a decreasing amount of iron toward the bottom of the filter. An exception to this last statement is found in the immediate vicinity of the under-drain where there is generally found an accumulation of precipitated iron.

The accompanying analyses give a fair idea of the accumulation of oxide of iron, nitrogen and calcium oxide, at different depths in the filters. There is some difference in the depth to which these substances have penetrated over the drains and throughout the rest of the filter.

CHEMICAL ANALYSES OF SAND TAKEN AT DIFFERENT DEPTHS IN PERCENTAGES.

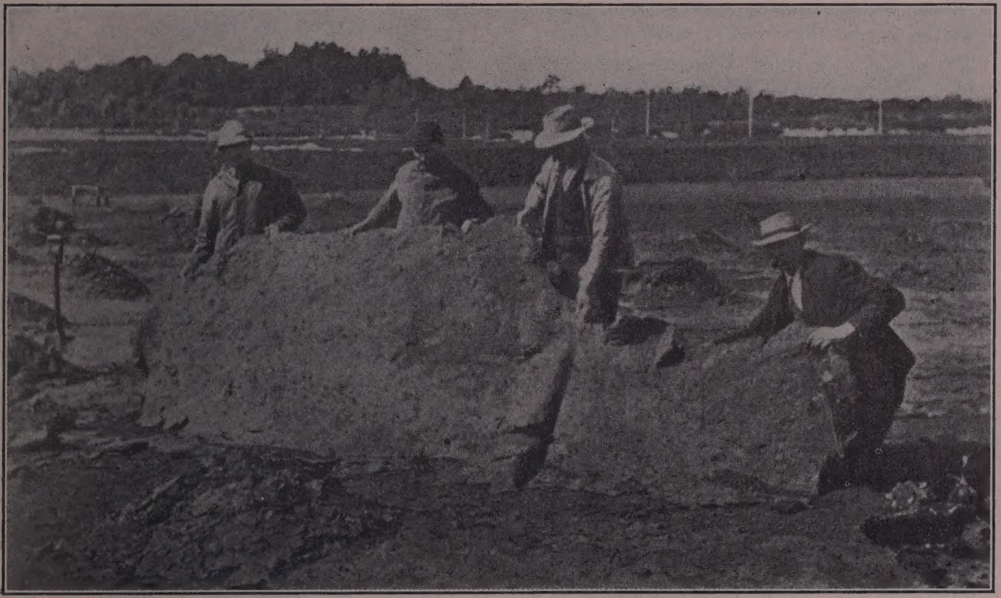
	Sample taken over drain.			Sample taken between drains.		
Dpt. of sample.	Ferric oxide.	Organic ntgn.	Calcium oxide.	Ferric oxide.	Organic ntgn.	Calc. oxide.
Top—2″	2.50	.146	.545	1.80	.089	.106
2″—6″	2.00	.060	.161	1.64	.052	.087
6″—12″	1.68	.022	.093	1.47	.031	.066
1′—2′	1.50	.013		1.33	.018	
2′—3′	1.31	.013		1.21	.020	
3′—4′	1.40	.016		1.16	.014	
4′—5′	1.36	.015		1.22	.007	
5′—6′	1.41	.013		1.41	.008	

The calcium oxide was not determined in these samples at a depth below 12 in. from the surface, for the reason that other examinations had revealed the fact that there was no accumulation of lime below this depth. The marked reduction in the amount of lime beneath the top 2 in of the sand is of particular interest. This is due probably in part to salts of lime carried in suspension by the effluent, and also probably to a considerable extent to the precipitation of lime by the liberation of carbonic acid gas from the water, as it comes in contact with the sand.

There is a marked reduction in the quantity of iron found at different depths in the sand, but this is not as noticeable as in the case of lime. A material amount of iron reaches the surface of the filters in the form of ferric hydrate, and is undoubtedly retained in the upper layer of the sand. There is also a large amount of sulphate of iron which finds its way in solution down into the lower portions of the filter; and, doubtless due to oxidation, more or less of the iron is precipitated in the sand.

There is a very noticeable exception to the rule of decrease of iron with the increase in the depth of sand in the filter in the case of the sand and gravel around the underdrains, where there is, much of the time, an ample supply of air and where the water is subject to more rapid oxidation due to its trickling from the fine sand into the coarse gravel. The oxide of iron in the sand which was mixed with the gravel amounted to 3.26 per cent., while in the sand immediately above it, it amounted to only 1.87 per cent.

The pipe joints of the underdrains in ten of the filters became almost completely clogged with a deposit of iron containing a little fine sand. An analysis of the material from these joints showed in one case 73.89 per cent. oxide of iron. These ten beds were practically disabled on account of the clogging of the joints in the manner already described, and in 1904 the underdrains in ten beds were entirely relaid. At this time the upper portion of the hub of each pipe was removed, and the pipes were not laid to joint within ⅜ in. Great care was also taken to grade the size of the cobbles placed around the joints. In this way it was hoped to furnish sufficient space so that the iron accumulating in the gravel around the underdrains could be washed out, and in that way the drains of the filter be kept in good condition. No trouble has been experienced since with a further clogging of the joints of these underdrains or the material about them.



Mat Formed on Filters by Suspended Solids from Unsettled Sewage.

The chemical efficiency of these filters has been reasonably good, considering the large amount of water which has been applied to them. This has undoubtedly been interfered with to a large extent by the trouble from clogging, both of the surface of the filter and of the underdrains. It has been found that, with an average of 125,000 gal. per acre per day, from 75 to 80 per cent. of the organic matter in the effluent from chemical precipitation could be removed, thus making the total reduction in organic matter in the crude sewage by both processes about 90 per cent. While with smaller quantities a still higher purification could doubtless be secured, it has been the policy to treat as large an amount of water as possible and get a reasonably good filtrate. Only at rare intervals,as in case of serious trouble from ice, has the filtrate from these filters been putrefactive. The filtrate when first leaving the underdrains is generally clear and without marked color. It is practically free from objectionable odor, and what little odor it has generally disappears in a very short time. There is apparently no increase in odor after the water leaves the filter.

The soluble salts of iron which are turned onto the filters and which complicate the treatment of the sewage, by all processes thus far tried, are very much in evidence in the filtrate. At first they are in solution and affect the color of the filtrate only slightly. After a short time, however, the absorption of oxygen by the water as it flows in the underdrains, together with perhaps some liberation of carbonic acid gas, causes a precipitation of ferric hydrate. There are times, when the filters appear to be in excellent condition, when this does not occur to any material extent. At other times, when the filter is getting into a bad condition, the amount of iron precipitated from the effluent is very large.

The filtrate when tested for dissolved oxygen almost without exception gives positive results. The results range from 5 to 50 per cent. saturation. This oxygen, no doubt, is derived in part from the ferric salts, but in any event is present and available to offset any tendency toward putrefaction.

The nitrification of the chemical effluent has never been very great. This may be due to several causes, but undoubtedly is due in part, at least, to the surface clogging which makes the access of air to the filter very slow. With the surface conditions such as have been described, the quantity of water passed through these filters has been too great for a high degree of nitrification.

The net result of the filtration of chemical effluent has been to produce an effluent which has been purified to the extent of about 90 per cent., but at a cost of from $10 to $12 for preliminary treatment and about $6 for filtration. Thus the expense of treating every million gallons of sewage by this method amounts to from $16 to $18.

Filtration of Septic Effluent.—For several years sewage at varying rates was passed through one of the large settling basins to test the practical operation of the septic process. A portion of this effluent was turned onto one of the sand filters.

The effluent contained at all times a material amount of very finely divided suspended matter, which was retained in the upper portion of the filter. The suspended matter, consisting to a large extent of sulphide of iron, penetrated the sand so that it was necessary to remove the clogged material by scraping, as in the case of filters receiving chemical effluent. The surface of the sand was continually black and emitted a disagreeable odor whenever wet.

The quantity of clogged sand removed from this filter was about the same as that removed from the filters receiving chemical effluent, although it was necessary to clean the surface more frequently. The quality of the filtrate was not as good as was obtained by filtering the effluent from the chemical treatment, and no better than that from settled or unsettled sewage. Quantitatively there was no advantage in the septic process as a preliminary treatment over chemical precipitation or sedimentation.

The sludge contained in the septic tank was exceedingly difficult to dispose of, as it was very offensive when spread upon the land and was filter pressed only with extreme difficulty and at much expense.

It is probable, in Mr. Eddy's opinion, that the combination of the septic treatment with sand filtration, if practicable for reasons other than cost, could be so manipulated as to produce a satisfactory filtrate at somewhat less expense than chemical precipitation with subsequent filtration.

Filtration of Settled Sewage.—For a number of years a portion of the sewage has been passed through some of the precipitation basins where a portion of the suspended matter has been removed and the effluent without chemicals has been turned onto the sand filters. The first part of the time the sewage was generally passed through three basins, each 40 ft. wide, 166⅔ ft. long and 7 ft. deep. The quantity of sewage settled in this way which has been filtered is shown by the following figures:

Year.	Av. per Day	Acres in use.	Av. per day per acre.
1900	2.909	10.64	.273
1901	0.937	5.9	.159
1902		none	
1903	0.390	3.9	.100

The rate of filtration of the settled sewage is a little less than that of the chemical effluent. The deterioration of the sand in the upper portion of the filter goes on in much the same way, although requiring somewhat more frequent cleaning, and possibly the removal of a somewhat smaller portion of the original sand. The amount of sewage matter removed in the case of settled sewage is a little more than with the chemical effluent, so that the total amount removed from the filters is about the same in the two cases.

During 1904, nine new filter beds were operated on sewage passed through one of the precipitation basins without the addition of chemicals. This basin was of the size already mentioned. Only the heaviest of the sewage was passed through these filters, which accounts for the very large percentage of suspended matter removed by sedimentation in the tank, viz., 50 per cent. When sewage was passed through this basin it was at the rate of from 15 to 20 million gallons per 24 hours; so that it passed through the settling basins at a comparatively high velocity.

The sewage, as it went to the filters, contained some of the coarser matters in suspension, so that the surface required cleaning once in from three to six weeks. The clogging material retained on and near the surface of the sand was of an entirely different nature from that resulting from the filtration of the chemical effluent. In the former case there was a larger quantity of organic matter, and even in a thoroughly well settled sewage it is of a more fibrous nature; while in the case of the chemical effluent it is of a gelatinous character. When the sedimentation is less complete, more of the fibrous material and some of the coarser particles pass to the filters and accumulate in time, so that upon drying it cracks and curls to a slight extent.

As the suspended matter from sewage accumulates on the surface of the beds, it becomes necessary to break up the layer mechanically, as with a rake. This treatment mixes the organic matter with the sand to a slight extent, and should be resorted to only when absolutely necessary to maintain a reasonable capacity of the filter. By this method it has been found possible to maintain the capacity of the filters at an average of about 125,000 gal. per acre per day of strong, settled sewage. This quantity is not widely different from that found in the case of the chemical effluent. So that quantitatively there appears to be only a little advantage in applying the chemical treatment over sedimentation to sewage of the quality received at these works.

The material removed from the surface of the filters contained a somewhat smaller proportion of sand than was the case when chemical effluent was applied. The weight of this material, as removed, amounted on the average to 92 lb. per cubic foot. The water contained at the time of these determinations was 12.36 per cent. An average sample of this refuse material taken from the filters during the first year of their operation, analyzed as follows: Moisture, 22.87 per cent.; organic nitrogen, 0.539 per cent.; ferric oxide, 2.58 per cent.

The cost of cleaning the surface of the filters varies with the physical condition of the surface at the time the cleaning is done. If the organic matter rests upon the surface of the sand, being unmixed with it to any extent, and is fairly dry, it can be peeled off without the removal of a very material amount of sand. This condition rarely exists when the sewage which has been turned onto the filters has been thoroughly well settled. In such cases the organic matter penetrates to a greater depth in the sand, and it becomes necessary to remove it by scraping. When in this condition the surface also does not dry out readily, so that it is generally removed in a damp or rather moist condition. In this case a much greater proportion of sand is present in the material removed.

It frequently becomes necessary to clean the filters during the cold season of the year, and the temperature at which this is done is a very important element. When the temperature remains very close to 32° F., the layer of clogged material on the surface freezes with only a very little of the sand attached to it. Under this condition it is possible to remove it rapidly without removing a material amount of sand. If, on the other hand, the temperature is much below 32°, the surface of the filters freezes to such a depth that a large amount of sand comes up with the surface material. Under such conditions the crust removed is often 2 or 3 in. thick where it is necessary to remove perhaps not more than a quarter or half an inch in thickness.

The following analyses of material removed under the three conditions described are of interest:

	Moisture.	Organic moisture in dried sample.
Clogging material peeled off dry	8.07%	1.126%
Clogging material scraped damp.	38.58	1.053
Clogging material removed in slightly frozen crust..........	24.79	.562

The amount of refuse material removed from these 9 beds which have received the partially settled sewage, is much greater than the amount removed from the filters previously referred to, which receive a well-settled sewage. In that case the amount removed was found to be substantially the same as that removed from the filters receiving chemical effluent, which was 3.3 cu. yd. per million gallons. In the case of the partially settled sewage, this figure is increased to 6.5. As in the case of the well-settled sewage, there was an increase in the proportion of organic matter in the material removed from the filter, over that in the material removed in the case of the chemical effluent, so there is, in the less completely settled sewage, a still greater proportion of organic matter, and this accounts for the greater amount of material removed per million gallons of sewage filtered.

There is a marked difference in the action of the filter on the iron salts in crude sewage from that described in the case of the chemical effluent. The iron is precipitated in the filter in the case of crude sewage, as the sulphide, and this generally begins at the bottom of the filter, due to lack of air. There is an accumulation of iron in the surface, also, due perhaps in part to the formation of some hydrate of iron in the sewage itself, and also probably to the precipitation in the surface layer in the form of sulphide. The iron in solution in the sewage is carried through the filter in much the same way as in the case of chemical effluent, and precipitated upon oxidation in the underdrains and channels after the water leaves the filter.

The purification on the sewage filtered through these 9 beds during the year 1904 amounted to 83.6 per cent. The effluent from settled sewage, although usually non-putrescible, has more often been putreactive than that from the filters receiving chemical effluent.

The cost of filtering the settled sewage was approximately $9 per million gallons filtered. To this should be added about $4 for disposal of sludge collected in the settling basin, making a total of $13 for this process.

Filtration of Unsettled Sewage.—During 1905 crude sewage passing directly from the grit chambers was filtered through all the beds, except a few reserved for chemical effluent. Day sewage was always selected for filtration. It was noticeable that the suspended matter in the sewage passing from the grit chamber was much coarser than that in the basin effluent, applied the year previous. It was possible later, on examining the sludge on the beds, to find the dividing line between the sludge from basin effluent and that from sewage passed only through the grit chamber.

A large amount of coarse and fibrous material is retained on the surface of the sand, and there forms a sort of woven mat. As soon as this mat begins to form, which is as soon as the first dose is applied, it retains the suspended matter in the sewage subsequently turned onto the filter. In this way the mat continually increased in thickness. After the water has passed through, this material dries, weather conditions permitting, shrinks, cracks and usually curls or lifts from the sand. While the suspended matter undoubtedly reaches the sand to a limited extent through the cracks in the mat, in the main the mat forms a very complete protection.

The large quantity of suspended matter in the unsettled sewage makes it necessary to clean the beds more frequently than in the case of settled sewage. It has been found necessary to rake over portions of the beds at least as often as once in two weeks. This material is generally raked up into piles and removed from the beds, only after it has accumulated to quite an extent. Great care is taken to prevent the mixing of any of this material with the sand, and it is interesting to note how clean and soft the sand immediately under the mat remains. The following analysis of this leather-like substance is interesting: Moisture, 6.13 per cent.; loss on ignition, 51.45 per cent., organic nitrogen, 2.31 per cent.

The quantity of refuse removed from the surface of these filters has amounted to about 14 cu. yd. per million gallons of sewage treated. It is very noticeable that the coarsest material settles nearest to the distributor; therefore, as would be expected, less sand is removed from this portion of the bed at each cleaning than from the center of the bed. This is well illustrated by the analyses given in the following table:

ANALYSES OF REFUSE MATERIAL REMOVED FROM BEDS 19 AND 23, NEAR AND REMOTE FROM DISTRIBUTORS.

	Bed 19		Bed 23	
	Near distributor.	Remote from distributor.	Near distributor.	Remote from distributor.
Moisture %..........	14.44	12.53	28.0	1.10
Loss on ignition, %..	11.29	6.76	16.16	9.87
Organic nitrogen, %.	.529	.377	.918	.827
Insol. fixed solids, %	72.86	87.55	76.71	85.32
Ferric oxide, %.....			.027	.023
Wgt. per cu. yd., lb...	1708	2210	1909	2224
Specific gravity of mass removed	1.001	1.310	1.131	1.318

The difference between the analyses given in this table and that immediately preceding, is due to the fact that the latter analyses are of the average of the material removed, which is quite different from the leather-like mat which is represented by the first set of analyses.

The difficulty caused by the precipitation of iron in the filter in the form of sulphide, as described under the heading of "Settled Sewage," has been experienced even more markedly in the filters receiving the unsettled sewage. The distribution of iron and organic matter through the sand of these filters is much more uniform than is the case in the filters receiving chemical effluent, as shown by the accompanying table of analyses:

ANALYSES OF SAND FROM BED RECEIVING UNSETTLED SEWAGE. IN PERCENTAGES.

	Moisture.	Loss on ignition.	Organic nitrogen.	Iron in terms of ferric oxide.	Total sulphur.	Sulphates in terms of sulphur.
Over drain—						
Top— 6″	5.56	0.89	.040	1.42	.0145	.0097
6″—12″	6.77	1.01	.0246	1.65	.0077	.0077
12″—24″	5.88	0.71	.0163	1.53	.0075	.0063
24″—36″	11.93	0.67	.0145	1.33	.0042	.0042
36″—48″	7.49	0.59	.0082	1.36	.0047	.0047
48″—60″	10.42	0.55	.010	1.38	.0047	.0047
Between drains—						
Top— 6″	4.48	1.13	.039	1.38	.0044	
6″—12″	5.03	0.87	.021	1.22	.0022	
12″—24″	4.41	0.68	.008	1.31	.0018	
24″—36″	4.83	0.65	.008	1.17	.0012	
36″—48″	6.35	0.73	.008	1.20	.0022	
48″—60″	8.20	0.66	.007	1.35	.0030	

The results given in the table show no material difference in the character of the sand over the drains and half way between, except where the black deposit occurs. It should be noted that the drains had not been relaid and that the sand had been undisturbed since the filter was built, a period of two years. There is somewhat more organic matter in the top layer, as would be expected, but below this it appears to be fairly uniform, and the iron is comparatively uniform throughout the filter. Most of the sulphur is usually in the top layer, but in places where there is a black deposit, there is still more. The amount of organic matter and iron appears to be less than that found in beds receiving chemical effluent. There appears to be no considerable storage of iron except in the black deposit, and here the percentage is low.

The portions of the filter which are found to be black, and which, as already described, contain sulphide of iron, hold the moisture tenaciously and oxidize very slowly, the oxidation beginning at the bottom and at the top of the bed, working gradually toward the middle. After the black material has had a chance to dry, the oxidation is very rapid.

The experience thus far would indicate that it would not prove practicable to filter as large a quantity of unsettled sewage of the character received as of settled sewage. During 1905 the filters have received an average of 91,000 gal. per acre per day. It should be noted in this connection that some of the underdrains appear to have become clogged in the joints. To just what extent this trouble exists is not known, but it is quite possible that the relaying of the drains, as has been done in the case of the other filters, would materially increase the quantity which could be filtered.

The filtrate from these filters has shown a good degree of purification, amounting to 89.2 per cent. It has at times been putrefactive and has emitted some odor; at other times it has been practically free from odor, and has kept well. There is every reason to believe that, with a careful manipulation, this process will continue to give a satisfactory filtrate.

The cost of this method of treatment has been approximately $13 per million gallons filtered. It should be borne in mind throughout the consideration of the work of these filters that they are receiving the very strongest sewage which comes to the disposal works.

Awarding Public Contracts to High Bidders.

The Public Works Commission of Tampa awarded a contract for sewer work about a year ago to a firm whose bid was higher than that of another responsible bidder. When the contract was written it contained provisions regarding the restoration of the property of private parties. The award was made the subject of an action by a local taxpayer and has recently been settled in his favor and against the Commission by the Florida Supreme Court. The syllabus of the decision, prepared by the court, reads as follows:

"Where the charter or incorporating act requires the officers of a city to award contracts for public works to the lowest bidder, a contract made in violation of its requirements is illegal and void, and neither the municipality nor its subordinate officers can make a binding contract for such work, except in compliance with the requirements of the law.

"The intention of the law in requiring such contracts to be let or awarded to the lowest responsible bidder for the work is to secure the public improvement at the lowest reasonable cost to the taxpayers. Therefore the incorporation into the advertisement for bids, or into the specifications of the work, upon which such bids are predicated, of illegal or unauthorized conditions or obligations upon the contractor, compliance with which on his part will necessarily and illegally increase the cost of the work, is not a letting of such contract to the lowest bidder within the meaning of the law, and will render the contract illegal and void.

"When a municipal corporation confines itself within the limits of its power and jurisdiction, it is not liable to an action for consequential damages to private property or persons (unless such liability is imposed by special constitutional provision or by statute), where the act complained of was done by it or its officers under and pursuant to authority conferred by a valid act of the Legislature, and there has been no want of reasonable care or want of reasonable skill in the execution of the power, although the same act, if done without legislative sanction, would be actionable.

While municipalities may by ordinance grant to individuals and corporations the privilege of occupying the streets and public ways for lawful purposes, such as railroad tracks, poles, wires, gas and water pipes, such rights are at all times held in subordination to the superior rights of the public, and all necessary and desirable police ordinances, that are reasonable, may be enacted and enforced to protect the public health, safety and convenience, notwithstanding the same may interfere with legal franchise rights. Thus a water company placing its pipes in the streets under a franchise contract with the city does so in subordination to the superior rights of the public, through its duly constituted municipal authorities, to construct sewers in the same streets whenever and wherever the public interest demands; and if in consequence of the exercise of this right the water company is compelled to relay its pipes, in the absence of unreasonable or malicious conduct, it has no cause of action against the corporation for reimbursement on account thereof. And the city in such a case has no authority voluntarily to burden itself or its taxpayers with the payment of damages necessarily consequent upon the reasonably careful and skillful execution of its authorized public works.

Letters to the Editor.

Technical Schools and the University.

Sir: The scholarly address made by Prof. William H. Burr at the ceremonies attending the opening of the current college year at Columbia University, which appeared in your journal on Oct. 6, is an admirable example of a high-grade ex-parte pedagogical argument. It appeals so cleverly to all the little points of personal self-esteem of every engineer that in the feeling of gratification at having all our pet hobbies raised to a plane of distinguished consideration we may overlook another side of this matter which this eminent engineer has not presented.

There is to-day no American civil engineer who has a higher professional standing than Prof. Burr, whose work as an educator and a consulting engineer is too well known to your readers to need mention here. It should be pointed out, however, that with the exception of some seven years or so spent with a great bridge company his experience has been essentially professional. Now the great majority of the graduates of a technical school never have any professional experience, in the real meaning of that term, and technical education mainly concerns them and their future careers. In these days, when the hair dresser and corn doctor have attained professional dignity in the opinion of many people and every chorus-girl rejoices in being a member of the "profesh," it is not generally appreciated that a professional man is only one who is retained to execute specific things requiring special learning and experience of a highly important kind that the employer does not himself possess. Consequently when a railroad company or a manufacturing company puts the graduate of a technical school on its pay roll at a regular salary to do whatever he is told to execute, that man is not accepting a professional engagement, although it is customarily so considered. It is probable that in the course of time the signification of "professional" will have been so steadily distorted that the term will be stretched to include any engagement of a man who has graduated from any of the higher classes of specialized schools, but for the present it is better for all concerned to look upon most graduates of engineering colleges as hired men, some of them holding places of great responsibility and others having nothing of any great weight resting on their shoulders.

As soon as this point of view is assumed, it will be apparent that there are many arguments to be made against any general assumption of the university becoming essential for the welfare of an engineering school. It must be admitted that in so far as its influence tends to impart to young men a respect for learning and a desire to see all things in their true relations, to stand for the right with firmness and yet with the tact which accomplished more than firmness in many cases, the university surroundings are admirable. It may be questioned, however, just how far the university exercises any such influence on the average youth who comes to its fold for precept and advice. Observation at a number of engineering colleges and technical schools leads to the belief that the more difficult courses in the former keep their pupils working harder and behaving better than the more liberal courses of a purely cultural nature leading to the bachelor of arts degree. The writer's opinion is that the young men in the technical schools of the country have a higher ambition, behave themselves better and work harder and with greater effectiveness than those in the colleges of arts. If this is so, it is difficult to see just how much good can come to them from being surrounded all the time with students whose influence is prejudicial to them. The most important thing a boy can learn in college is to do his work promptly and as well as he can; the technical school insists on such a spirit, while it is self-evident that most universities do not, otherwise there would have been none of the recent scandals over athletics and similar subjects which have led President Eliot of Harvard to demonstrate in forceful words his great comprehension of educational conditions and tendencies.

There is no objection to the close association of engineering and arts colleges provided in bringing this about the former are not made to give up advantages of location nor are their students ranked below or behind those in the classes in arts. So long as a union of the two kinds of colleges will not result in detriment to engineering students, who must be taught to work hard and long over difficult subjects and who must look forward to lives spent under the restraints of salaried positions, there is little to be said against it, but it is pretty hard for the rapidly rising and dominant engineering school to have the obsolete courses and Willie-boy classes of the average arts colleges hung about its neck like a millstone on an ambitious swimmer. The technical school of America has been developed independently of any liberal arts educational institutions. Just so long as the Rensselaer Polytechnic Institute, the Worcester Polytechnic Institute, the Massachusetts Institute of Technology and Stevens Institute of Technology, to mention a few of the pioneers, clung to the educational models set by arts colleges, they did not have much influence. But when they themselves grasped the meaning and purpose and dignity of technical education and found ways and means for giving it to their students, then America had its first experience in engineering education. Its success has not been because of anything done for it by the universities, but rather in spite of the retarding influence of the older seats of learning. This being the history of technical education in this country, it must be repeated that in some respects Professor Burr's address, instructive and interesting as it is, brings up for consideration some features of engineering education on which a material difference of opinion probably exists.

Yours truly, Alumnus.

Underground Water Investigations of the U. S. Geological Survey.

Sir: A leading article entitled "Local Irrigation," appears in the issue of Sept. 29 of The Engineering Record, in which the value of small systems of irrigation is suggested and the necessity for comprehensive investigations of the occurrence of ground water supplies is pointed out. The following statements are quoted from the article: "Here is a good task for the United State Geological Survey. A reliable underground supply, the result of subterranean storage of the run-off, is very valuable, yet very litttle has been done toward a systematic survey."

Some of those who are familiar with the investigations of the Hydrographic Branch of the Geological Survey, and especially those officially connected therewith, are wondering whether or not the lack of familiarity with the work of the

Hydrographic Branch, as shown by the statement above quoted, is general throughout the engineering profession. One of the principal objects of the Geological Survey during the past twelve years has been the study of the specific questions mentioned in said article, and numerous reports have been printed by the United States Government and distributed gratuitously. Moreover, these reports have apparently been widely used and have resulted in the establishment of local irrigation systems and municipal and industrial water supplies. The rapidity with which various editions are exhausted is sufficient testimonial to the popularity of the work. Why, then, should there be a lack of information upon the part of the engineering profession with reference to these investigations?

Perhaps the work is not judiciously advertised, or it may be that the volumes are not distributed among those persons who would make the best use of them. It is also possible that the investigations are of such exclusively local significance that their notoriety is confined to the special regions in which the studies are made. It is evident that something might be improved; were it not so, such expressions as that above quoted would not be likely to appear in one of the leading engineering journals of the United States.

It may be that you or some of your readers can make helpful suggestions. The work is performed for the benefit of American citizens, and therefore the main object should be to place the results before the people in the best possible way. Those who have been placed in charge of this work probably do not view the matter from all possible standpoints. Therefore, if you can secure suggestions, the compliance with which will make the Hydrographic work of the Geological Survey more widely known than it is at present, no one will be more grateful than those who are responsible for its success.

In order that a fairly comprehensive idea of the scope of the Survey's work upon ground waters may be disseminated, I present below a list of reports already issued and of the investigations now in progress.

Water Supply and Irrigation Papers; U. S. Geological Survey; dealing with ground-water investigations and their economic development. No. 5, Irrigation Practice On the Great Plains, by E. B. Cowgill; 1897, 39 pp., 12 pls. No. 6, Underground Waters of Southwestern Kansas, by Erasmus Haworth; 1897, 65 pp., 12 pls. No. 8, Windmills for Irrigation, by E. C. Murphy; 1897, 49 pp., 8 pls. No. 12, Underground Waters of a Portion of Southeastern Nebraska, by N. H. Darton; 1898, 56 pp., 21 pls. No. 13, Irrigation Systems in Texas, by W. F. Hutson; 1898, 68 pp., 10 pls. No. 14, New Tests of Pumps and Water Lifts Used in Irrigation, by O. P. Hood; 1898, 91 pp., 1 pl. No. 21, Wells of Northern Indiana, by Frank Leverett; 1899, 82 pp., 2 pls. No. 26, Wells of Southern Indiana (Continuation of No. 21), by Frank Leverett; 1899, 64 pp. No. 29, Wells and Windmills in Nebraska, by E. H. Barbour; 1899, 85 pp., 27 pls. No. 30, Water Resources of Lower Peninsula of Michigan, by A. C. Lane; 1899, 97 pp., 7 pls. No. 41, The Windmill; its Efficiency and Economic Use, Part I, by E. C. Murphy; 1901, 72 pp., 14 pls. No. 42, The Windmill, Part II (continuation of No. 41); 1901, 73-147 pp., 15-16 pls. No. 59, Development and Application of Water in Southern California, Part I, by J. B. Lippincott; 1902, 95 pp., 11 pls. No. 60, Development and Application of Water in Southern California, Part II, by J. B. Lippincott; 1902, 96-140 pp. No. 78, Preliminary Report On Artesian Basins in Southwestern Idaho and Southeastern Oregon, by I. C. Russell; 1903, 53 pp., 2 pls. No. 101, Underground Waters of Southern Louisiana, by Gilbert D. Harris, with discussion of their uses for water supplies and for rice irrigation, by M. L. Fuller; 1904, 98 pp., 11 pls. No. 102, Contributions to the Hydrology of Eastern United States, 1903, M. L. Fuller, geologist in charge; 1904, 522 pp. No. 104, The Underground Waters of Gila Valley, Arizona, by W. T. Lee; 1904, 71 pp., 5 pls. No. 106, Water Resources of the Philadelphia District, by Florence Bascom; 1904, 75 pp., 4 pls. No. 111, Preliminary Report On the Underground Waters of the State of Washington, by Henry Landes; 1905, 85 pp., 1 pl. No. 112, Underflow Tests in the Drainage Basin of Los Angeles River, by Homer Hamlin; 1905, 55 pp., 7 pls. No. 114, Underground Waters of Eastern United States, by M. L. Fuller, geologist in charge; 1905, 285 pp., 18 pls. No. 117, The Lignite of North Dakota and Its Relation to Irrigation, by F. A. Wilder; 1905, 59 pp., 8 pls. No. 118, Geology and Water Resources of a Portion of East-Central Washington, by F. C. Calkins; 1905, 96 pp., 4 pl. No. 123, Geology and Underground Water Conditions of the Jornado del Muerto, New Mexico, by C. R. Keyes. No. 136, Underground Waters of Salt River Valley, Arizona, by W. T. Lee; 1905, 196 pp., 23 pls. No. 137, Development of Underground Waters in the Eastern Coastal Plain Region of Southern California, by W. C. Mendenhall; 1905, 140 pp., 7 pls. No. 138, Development of Underground Waters in the Central Coastal Plain Region of Southern California, by W. C. Mendenhall; 1905, 162 pp., 5 pls. No. 139, Development of Underground Waters in the Western Coastal Plain Region of Southern California, by W. C. Mendenhall; 1905, 105 pp., 8 pls. No. 142, The Hydrology of San Bernardino Valley, California, by W. C. Mendenhall; 1905, 124 pp., 12 pls. No. 149, Preliminary List of Deep Borings in the United States, second edition with additions, by N. H. Darton; 1905, 175 pp. No. 153, The Underflow in Arkansas Valley in Western Kansas, by C. S. Slichter; 1906, 90 pp., 3 pls. No. 154, The Geology and Water Resources of the Eastern Portion of the Panhandle of Texas, by C. N. Gould; 1906, 64 pp., 15 pls. No. 157, Underground Water in the Valleys of Utah Lake and Jordan River, Utah, by G. B. Richardson; 1906, 81 pp., 9 pls. No. 158, Preliminary Report On the Geology and Underground Waters of the Roswell Artesian Area, New Mexico, by C. A. Fisher; 1906, 29 pp., 9 pls. No. 181, Geology and Water Resources of Owens Valley, California, by W. T. Lee; 1906, 27 pp., 6 pls. No. 182, Flowing Wells and Municipal Water Supplies in the Southern Portion of the Southern Peninsula of Michigan, by Frank Leverett and others. No. 183, Flowing Wells and Municipal Water Supplies in the Middle and Northern Portions of the Southern Peninsula of Michigan, by Frank Leverett and others. No. 184, Underflow of the South Platte Valley, by Charles S. Slichter and Henry C. Wolff. No. 188, Water Resources and Their Development in the Rio Grande Valley, New Mexico, by W. T. Lee.

Professional Papers; U. S. Geological Survey; No. 17, Preliminary Report On the Geology and Water Resources of Nebraska West of the One Hundred and Third Meridian, by N. H. Darton; 1903, 69 pp., 42 pls. No. 32, Geology and Underground Water Resources of the Central Great Plains, by N. H. Darton; 1905, 433 pp., 72 pls. No. 44, Underground Water Resources of Long Island, New York, by A. C. Veatch, C. S. Slichter, Isaiah Bowman, W. O. Crosby and R. E. Horton; 1906, 394 pp., 34 pls. No. 46, Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas, by A. C. Veatch; 1906.

Reports in Preparation.—Ground Waters of Missouri, Their Geology and Utilization, by Edward M. Sheppard. Ground Waters of the Coastal Plain of Texas, by Thomas U. Taylor. Underground Water Resources of Tennessee and Kentucky west of the Tennessee River, by L. C. Glenn. Geology and Water Resources of Owens Valley, California, by W. T. Lee. Flowing Wells and Municipal Supplies in the Southern Peninsula of Michigan, by Frank Leverett. Underflow of the South Platte Valley, Nebraska, by C. S. Slichter. Well-Drilling Methods, Their Geologic and Engineering Aspects, by Isaiah Bowman. Underground Waters in San Pete and Central Sevier Valleys, Utah, by G. B. Richardson. Geology and Water Resources of the Big Horn Basin, by C. A. Fisher. Ground Waters of the State of Maine, by F. G. Clapp. Ground Waters of Connecticut, by H. G. Gregory. Ground Waters of the Triassic Area in New York, New Jersey and Pennsylvania, by M. L. Fuller, W. T. Lee and others. Ground Waters of the Coastal Plain of Virginia, by Samuel Snaford. Ground Waters of the Coastal Plain of North Carolina, by M. L. Fuller and B. L. Johnson. Ground Waters of Florida, by E. H. Sellards. Ground Waters of the Blue Grass Region of Kentucky, by George B. Matson. Ground Waters of Ohio and Indiana, by M. L. Fuller and others. Ground Waters of Iowa, by W. H. Norton, W. S. Hendrixson and others. Ground Waters of Southern Minnesota, by F. G. Clapp and W. S. Hendrixson. Ground Waters in Northern Texas and Oklahoma, by C. H. Gordon. Ground Waters of Beaver Valley, Utah, by W. T. Lee. Ground Waters of the Sun River Valley, Montana, by C. A. Fisher. Ground Waters of Oregon, by W. C. Mendenhall. Ground Waters of San Joaquin Valley, California, by W. C. Mendenhall.

It will be seen that the investigations and reports above noted include determinations of the occurrence and availability of ground waters in various parts of the country, also practical tests of methods for determining the rate of underground flow, and studies of the efficiency of windmills and other types of pumping engines. In addition to all this, studies are made of the character of water from various water bearing strata and its adaptability for irrigation, domestic supply and manufacturing purposes.

Very respectfully,
M. O. Leighton,
Acting Chief Hydrographer.

Washington, Oct. 6.

[The excellent work of the Geological Survey is well known, but the extent of its underground water investigations shown by the preceding bibliography is surprisingly comprehensive. Nevertheless these papers do not give the information referred to in the article mentioned by Mr. Leighton; the information in question is a clear and concise statement of what to do, useful to men of little education, who settle in places where ground water must be developed to supplement dry farming or the latter will be unsuccessful. Some data of this sort have already been issued by the Agricultural Department.]

Painting Roads With Tar to prevent dust has been tried in several places by Mr. Frank G. Howell, county engineer of Surrey, England. The surface is thoroughly swept when perfectly dry until the road metal is exposed. Hot tar is then poured on the road and brushed well into it, after which the surface is sprinkled with sand. The initial expense is said to be small and a considerable amount of dust is prevented. On wind-swept open roads the surface is preserved by the tar, and the cost of the tarring is practically saved. On roads made of crushed granite, near towns, the cost is not saved by the decreased wear, but the dust is lessened. The tarring can only be properly done during perfectly fine weather, and, unfortunately, however carefully the work is executed, the surface is liable to churn up during the heavy rains of the early winter.